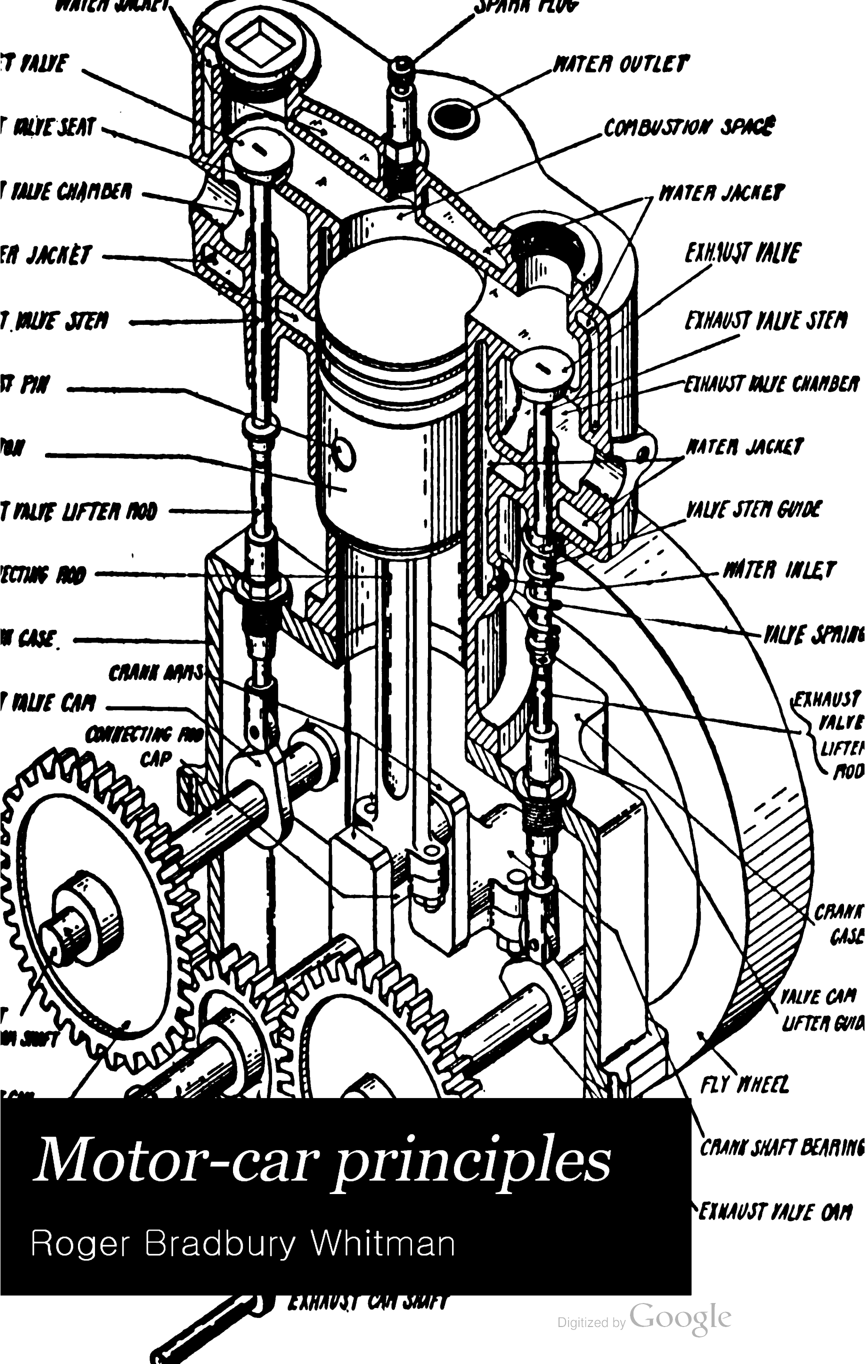


Motor-car principles

Roger Bradbury Whitman

MOTOR-CAR PRINCIPLES

MOTOR-CAR PRINCIPLES

THE GASOLINE AUTOMOBILE

BY

ROGER B. WHITMAN

AUTHOR OF "GAS-ENGINE PRINCIPLES"

ILLUSTRATED

NEW EDITION, COMPLETELY REVISED

D. APPLETON AND COMPANY

NEW YORK, LONDON MCMXVI

Printed in the United States of America

INTRODUCTION

THE development of the gasoline automobile at home and abroad has produced a great variety of designs, good, bad, and indifferent, but the advancement of the industry has weeded out the unsatisfactory and improved the good until with few exceptions the leading makes show a striking similarity in all but details. The advantages of certain forms of construction have been recognized, and their adoption by the large majority of makers has produced what may be called a standard type.

The object of this book is to explain the principles that underlie automobile construction and operation, and to illustrate the movements and mechanical combinations adopted in present-day practice. It is not the intention to explain the exact details of construction of the different cars, and the illustrations have been prepared with the sole

object of making the principles clear, for with an understanding of these there should be no difficulty in comprehending any particular application of them.

The advantages of magneto ignition for internal combustion engines are so obvious that designers and inventors have directed their attention to the perfection of apparatus that will improve present methods. The number of systems proposed for the purpose is very large in comparison with the number accepted by automobile manufacturers, and as in a work of this size it would be impossible to describe the many methods for the application of the magneto that are on the market, attention has been given only to those that are in actual, every-day use.

The lubrication table on pages 326 and 327, which was prepared by Mr. T. D. Hanauer, is reproduced through the courtesy of the *Scientific American.*

R. B. W.

FLUSHING, N. Y.

CONTENTS

CHAPTER I

GASOLINE-ENGINE PRINCIPLES

CHAPTER II

ENGINE PARTS

CHAPTER VI

IGNITION PRINCIPLES

CHAPTER VII

MAGNETO PRINCIPLES

CHAPTER VIII

TRUE HIGH-TENSION MAGNETOS

CHAPTER IX

TRANSFORMER MAGNETOS

CHAPTER X

BATTERY IGNITION SYSTEMS

CHAPTER XI

COMBINED MAGNETO AND BATTERY SYSTEMS

CHAPTER XII

SPARK PLUGS, CABLES, TERMINALS, AND COUPLINGS

CHAPTER XIII

TRANSMISSION

CHAPTER XIV

TRANSMISSION—(*Continued*)

CHAPTER XV

RUNNING GEAR

LIST OF ILLUSTRATIONS

MOTOR CAR PRINCIPLES

CHAPTER I

GASOLINE ENGINE PRINCIPLES

THE action of a steam, gasoline, or hot-air engine depends on the principle that when air or other gas is heated it expands, and that if it is confined in a space that will not permit it to expand, in striving to do so it creates pressure against all parts of the chamber in which it is contained. The more a gas is heated, the more it will expand if it is free to do so, and if not free, the greater will be the pressure that it will exert in striving to expand. Pressure may thus be generated by heat, and following along similar lines, heat may be produced by pressure, for when the pressure of

a gas is increased by compressing it, or forcing it to occupy a smaller space, the gas will become heated. The reverse is also true, that when a gas is cooled, its volume is reduced, which reduces the pressure that it exerts; similarly, reducing the pressure by permitting the gas to expand reduces its temperature.

To state these principles in another form, to create pressure in a gas it must either be heated or compressed into a smaller space, and to reduce its pressure it must either be cooled or permitted to expand.

The action of a locomotive, the most familiar type of steam engine, is no mystery, and the production of steam in the boiler, its passage to the cylinder, and the application of its steady pressure against first one side of the piston and then the other, resulting in the turning of the driving wheels, are well understood. Water being converted into steam in the boiler, pressure is created because of the tendency of the steam to expand,

but the only place in which it may expand is the cylinder, where in so doing it moves the piston.

A gasoline engine is similar to a steam engine in that its piston is moved by the pressure exerted by a heated and expanding gas; it is different in that the pressure is produced inside of the cylinder by the combustion of an inflammable mixture of gasoline vapor, instead of being generated in a boiler away from the cylinder. The heat of the combustion creates great pressure, and as the piston is the only part that can give before it, it is moved from one end of the cylinder to the other, this motion being utilized in the turning of the crank shaft. The combustion, which is so rapid that the generally accepted term for it is explosion, can occur only after the mixture has been drawn into the cylinder, and so prepared that it ignites quickly and burns completely, with the object of obtaining the greatest possible heat from it in the shortest possible time. In or-

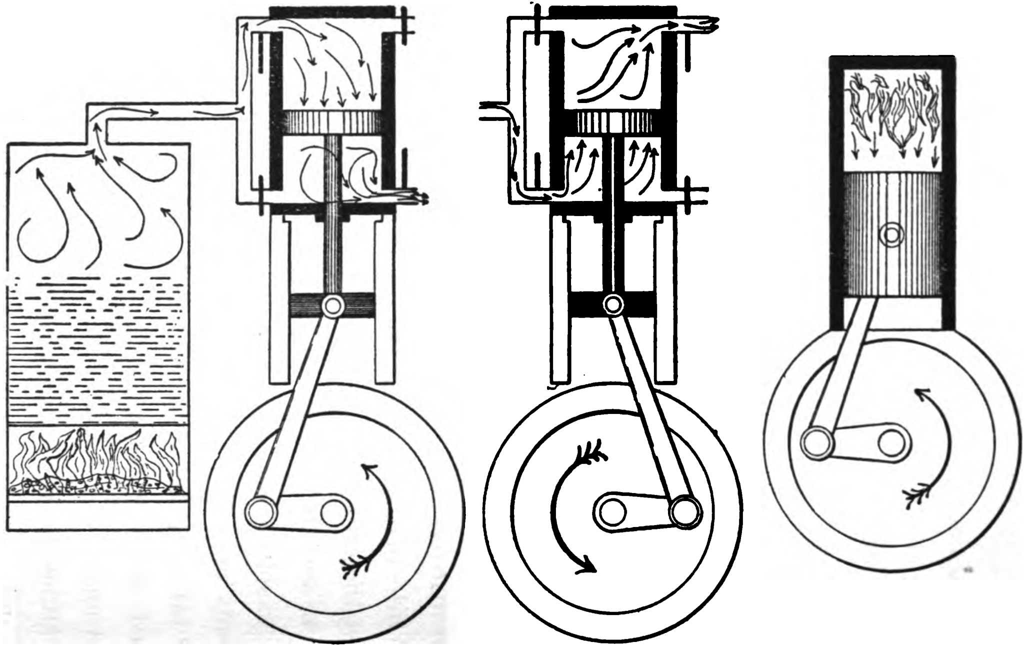


FIG. 1.—STEAM ENGINE (EXTERNAL COMBUSTION) AND GAS ENGINE (INTERNAL COMBUSTION).

der that one explosion may be followed by another, the burned and useless products of combustion must be expelled to make place for a fresh charge of the inflammable mixture.

These successive events, forming a **cycle,** must be performed as long as the engine runs, and the constantly changing pressure in the cylinder due to the movement of the piston allows a fresh charge to enter, prepares it, and expels the products of combustion after the pressure that they have exerted has been utilized.

While in the great majority of steam engines the steam acts first on one side of the piston and then on the other, in an automobile gasoline engine the pressure is exerted on only one side, the combustion of the mixture taking place between the piston and the closed end, or **head,** of the cylinder. The other end of the cylinder is open, and the piston slides between the ends, its movement from one end to the other, called a **stroke,**

corresponding to a half revolution of the crank shaft.

Gasoline engines are divided into two classes, according to the number of strokes of the piston that are necessary to accomplish the cycle; in the most usual type, four strokes are necessary, the class being called the four-stroke-cycle, or **four-cycle**, in distinction to the two-stroke-cycle, or **two-cycle**, in which but two strokes are necessary.

Of the five events that compose the cycle, three (the **inlet**, during which the fresh mixture enters the cylinder, its **compression** or preparation, and the **exhaust** of the burned gases) are performed by the piston; during the **power** event the piston is moved by the pressure resulting from the combustion, while the **combustion** event is due to an outside source. In the four-cycle type of engine, which is in almost universal use for automobiles, the events are considered with reference to the movement made by the piston during which they are performed, and may

be called the **inlet, compression-combustion, power,** and **exhaust strokes.** In order that the engine may continue to run, it is obvious that the events must be performed in the correct order, and that the failure of one will affect all the others.

During the inlet stroke, a charge of fresh mixture enters the cylinder as the piston makes an outward stroke from the closed toward the open end. When the piston makes the following inward stroke, the mixture is compressed and combustion occurs, the pressure from which drives the piston outward on the power stroke. This is followed by another inward stroke, which pushes the burned gases out of the cylinder. It will be seen that power is developed during only one stroke of the four, the other three being required in the preparation for the following power stroke. The movement of the piston over these three dead strokes is secured by attaching to the crank shaft a heavy **fly wheel,** the momentum of which, acquired

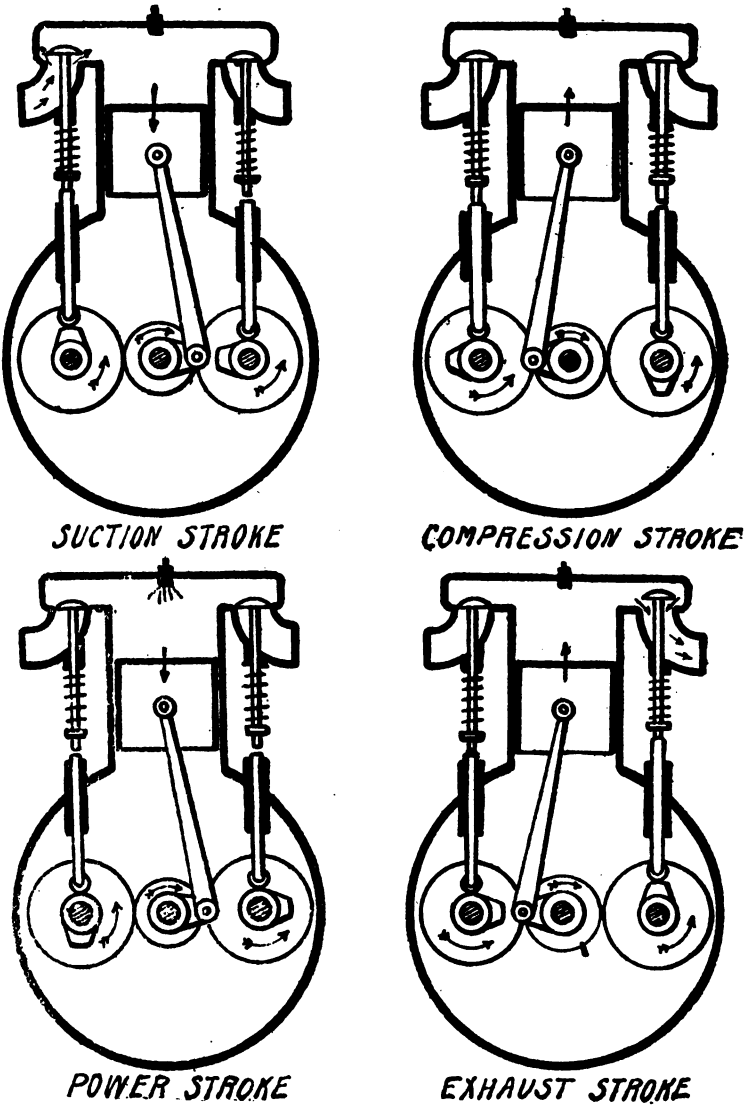


FIG. 2.—GASOLINE ENGINE CYCLE.

during the power stroke, keeps the crank shaft revolving and the piston in motion while the events are performed.

The space between the piston and cylinder head in which the combustion occurs is called the **combustion space**, and the **inlet and exhaust valves** open into it, the first being that by which the fresh mixture enters, and the second that by which the products of combustion escape. The device for igniting the mixture projects into the combustion space, and the means of ignition in universal use for automobile engines is an electric spark.

INLET STROKE

During the stroke (Fig. 2), the piston is moved outward by the crank shaft, which is revolved either by hand or by the momentum of the fly wheel. This movement increases the size of the combustion space, thereby reducing the pressure in it, and the higher pressure of the atmosphere outside of the cylinder will force fresh mixture into the combus-

tion space, the inlet valve being open to admit it. If the piston moves slowly, the mixture will be able to enter fast enough to keep the pressure in the combustion space equal to that outside, but at the high speed at which a gasoline engine is run the piston will reach the end of its stroke before a complete charge has had time to enter, so that the pressure in the combustion space will still be below that of the atmosphere. If the inlet valve closed at this point so that no more mixture could enter, the combustion of the partial charge would result in a lower pressure than would be possible with a full charge; the inlet valve should therefore remain open until the piston reaches the point of its next inward stroke at which the pressure in the cylinder equals that outside.

COMPRESSION-COMBUSTION STROKE

The compression and the combustion of the charge occur during the next inward stroke of the piston.

The period between the bringing together of the liquid gasoline and air and its admission to the cylinder is too brief to secure perfect combination, and the mixture that results is not satisfactory. A portion of the air will not have been able to come into contact with the gasoline, and much of the liquid will not have been vaporized; what passes into the cylinder consists of pure air, liquid gasoline, and a more or less perfect mixture of the two. The combustion of this would be slow and incomplete, resulting in loss of power and waste of fuel. In order to render the mixture more perfect, advantage is taken of the heat that is produced by compression; the inward stroke of the piston raises the temperature of the mixture by compressing it, the heat rendering the gasoline more volatile, and the compression forcing it into combination with the air. Even this does not result in the formation of a perfect mixture, for the period is too short to effect it. The failure of an engine to deliver full power

may often be traced to this condition, for the air and gasoline vapor, instead of being thoroughly combined and mixed, will be in layers, so to speak, and the combustion will be slow and uneven. Future development of the internal combustion engine will no doubt eradicate this, to the increase of efficiency and economy.

The charge of inflammable mixture can produce a certain amount of heat, and the more rapidly and completely this heat is obtained, the greater and more sudden will be the rise in pressure. The pressure will be greater when the mixture is contained in a small space than when in a large, and as the combustion space is smallest when the piston is at its inmost point, the greatest pressure will be obtained if combustion is complete at this point. If the combustion of the mixture were instantaneous, it should be ignited at this point; but even though very rapid, it nevertheless burns slowly enough to make it necessary to ignite it sufficiently before the

end of the stroke to have the combustion complete as the piston comes into position to move outward. The instant at which the mixture must be ignited in order to produce this result depends on the speed of the piston, for the interval between the ignition of a good mixture and its complete combustion does not vary to any great extent. When the piston is moving slowly, the mixture may be ignited toward the end of the compression stroke, for there will be sufficient time for complete combustion by the time the stroke is ended; but when moving at high speed, ignition must occur much earlier in the stroke, as otherwise the piston will have completed the compression stroke and begun to move outward on the power stroke before the mixture is entirely burned. The instant at which ignition occurs also depends on the mixture that is used, for its quality and proper combination make a difference in the rapidity with which it burns. The better the quality of the mixture, the faster and more

completely it will burn, and ignition may occur later in the stroke than would be possible with a mixture of poor quality. As the mixture is ignited by the passing of an electric spark in the combustion space, the difference in the instant at which it occurs may be secured by permitting the spark to pass earlier or later, and this is under the control of the driver.

When ignition occurs early in the compression stroke, the spark is said to be **advanced,** in distinction to a **retarded** spark, which passes when the compression stroke is more nearly complete.

If the spark is advanced too much, combustion will be complete before the piston has reached the end of the compression stroke, and it will be necessary to force it to the end of the stroke against the pressure by the momentum of the fly wheel, in order that it may get into position to move outward on the power stroke. In such a case, the momentum may not be sufficient to over-

come the pressure, and the piston will be brought to a stop. A retarded spark results in the combustion of the mixture being completed after the piston has begun to move outward on the power stroke, and the pressure will then be reduced because it is exerted in a larger space, the piston consequently being moved with less force; if the spark is still further retarded, the combustion will not be complete by the time the exhaust begins, and the heat from only a portion of the mixture will be utilized, because it will still be burning as it is forced out of the cylinder.

The position at which the spark occurs is one of the means by which the speed of the engine is controlled, for the low pressure that results from a retarded spark moves the piston at low speed, while the greater pressure from an advanced spark drives the piston outward with more force and higher velocity.

While high compression of the charge improves its quality, and results in combus-

tion being more rapid and complete, it has limits, and if carried too far the heat generated by the compression will be sufficient to ignite the mixture. This would have a bad effect on the operation of the engine, for the pressure would then be produced at the wrong point of the stroke, retarding instead of assisting the revolution of the crank shaft. Modern practice has shown that in engines that are maintained at a proper temperature the best results are obtained by compressing the mixture to from sixty to eighty pounds to the square inch; there are instances in which a higher compression is obtained, but the liability to ignite the mixture prematurely makes it undesirable.

POWER STROKE

The increasing size of the combustion chamber as the piston moves outward on the power stroke permits the gases to expand, and in doing so the temperature will fall, the pressure decreasing in consequence. A fur-

ther decrease in pressure is caused by the hot gases being in contact with the metal cylinder and piston, which absorb heat. The more slowly the engine runs, the longer the gases will be in contact with the cylinder walls, and the more opportunity there will be for loss of heat from this cause; at higher speeds, there will be less time for heat to be absorbed by the cylinder walls, and more will be utilized in expanding the gases and producing work.

Even at the outmost position of the piston, the combustion space will not be large enough to permit the gases to expand until their pressure has dropped to that of the atmosphere, so that they will still be exerting pressure. By opening the exhaust valve, the gases will have an outlet for expansion, and will begin to rush out. While the pressure might be utilized against the piston to the end of the power stroke, it has been found that better results are obtained by opening the exhaust valve before the piston reaches

the end of the power stroke. There is then a higher pressure forcing the gases out than there would be later in the stroke, and the greater quantity of gases that escapes leaves less to be expelled during the exhaust stroke.

EXHAUST STROKE

The inward movement of the piston pushes out of the open exhaust valve the gases that have not escaped through their desire to expand. The exhaust valve remains open for the entire stroke, but when the engine is running at high speed the piston moves so rapidly that the gases cannot escape fast enough to prevent their being slightly compressed. When the piston is at its inmost point, the gases are still flowing through the valve because of this slight compression, and if the valve closed, a portion would be retained. The best results come from the closing of the exhaust valve not at the end of the exhaust stroke, but a short time after the piston has begun to move outward again, during which

period the compression forces the gases out. The exhaust valve closes at the point when the slight compression has been reduced to the pressure of the atmosphere by the escape of the gases and the enlargement of the combustion space.

If the piston completely filled the combustion space when at its inmost point, all of the burned gases would be expelled, but the necessity for leaving a space in which combustion may take place renders this impossible, and a small portion of the burned gases therefore remains in the cylinder. The space between the cylinder head and the piston when at its inmost point, called the **clearance**, should be as small as possible, in order that the amount of these gases remaining in the cylinder may not be sufficient to contaminate the fresh charge and weaken the pressure of its combustion.

The passages through which the burned gases are led away from the cylinder must be large and free from obstructions, for if a free

flow is not permitted back pressure will be set up, which will prevent the largest possible amount of gases from escaping, and leave a greater portion to contaminate the fresh charge.

The power that a gasoline engine is capable of developing depends on the size of the cylinder, the pressure acting on the piston, and the speed at which it operates. A steam engine, which obtains its pressure from a boiler, can do work as soon as the steam is turned into the cylinder, but a gasoline engine must be running before it can be called on to deliver power. Because of the cycle of events on which its operation depends, the piston must be forced to perform the inlet and compression strokes before pressure can be developed, and it is necessary to revolve the crank shaft by outside means until a charge of mixture has been taken into the cylinder, compressed, and ignited, when the engine begins to work by the pressure from the combustion, and takes up its cycle. Not

until this has been done can it be called on to do work.

A steam engine can be made to deliver more power than it is built for by increasing the pressure acting against its piston, and the full pressure of the boiler can be utilized when extra work is necessary. The power developed by a gasoline engine being greatly dependent on its speed, and there being no reserve by which greater power can be developed in emergencies, it is necessary for an engine of this type to be perfectly adapted to the work that is desired of it. At excessive speeds the piston acquires great momentum, which must be overcome at each end of a stroke by the crank shaft, and while a speed above normal may be attained, it results in the quick destruction of the bearings and the severe straining of the engine. The best results in efficiency and long life accompany the running of the engine at the slowest speed possible for the development of the required power.

CHAPTER II

ENGINE PARTS

THE sudden and powerful outward movements of the piston under the pressure from the combustion are transmitted to a **crank shaft**, which must be of great strength in order to resist the heavy strains under which it operates. It is made of the best steel available for the purpose, and has as many **cranks** as the engine has cylinders. The cranks are generally made in one piece with the shaft for the sake of strength, and for stiffness there are as many **bearings** as possible. The number of bearings for the crank shaft of an engine with four or more cylinders depends on the arrangement of the cylinders. If the cylinders are evenly spaced, there will be room for a bearing between each pair of cranks, so that a four-cylinder engine will have five bear-

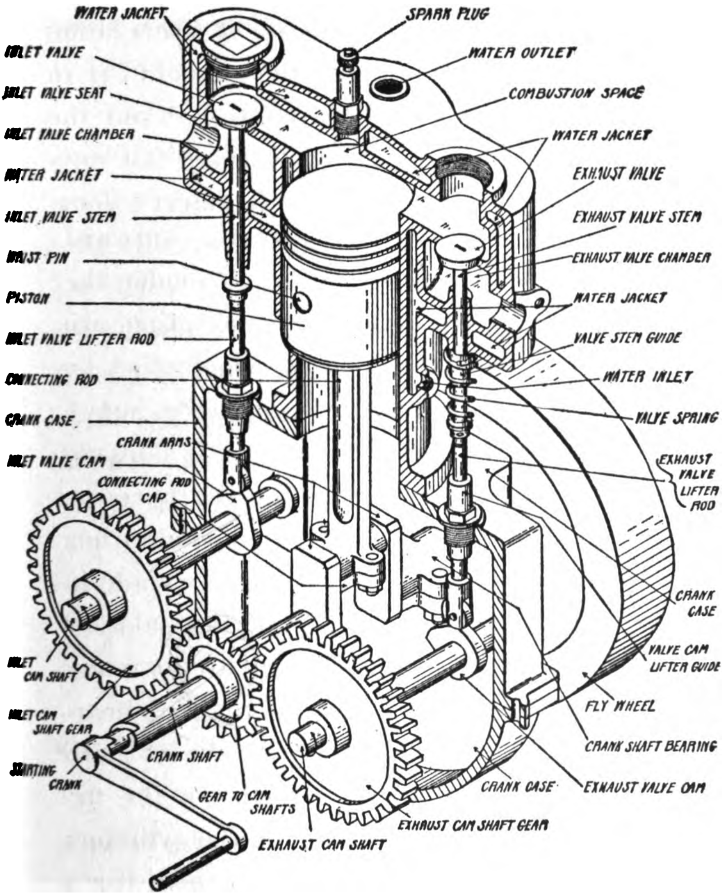
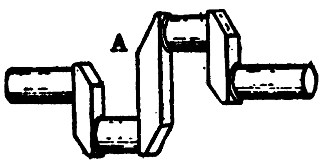


Fig. 3.—Gasoline Engine in Section.

ings, one at each end, the other three being between the cranks. If the cylinders are in pairs, there will not be room between the cranks of a pair for a bearing, the only space for it being between the pairs; a four-cylinder engine built in this way will thus have but three bearings, one at each end and one in the center. Crank shafts are described by their bearings as three, five, etc., point crank shafts.



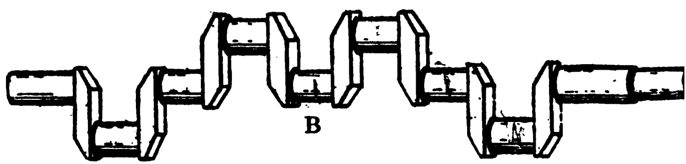


FIG. 4.—A, TWO-THROW CRANK SHAFT; B, FOUR-THROW CRANK SHAFT.

The relative positions of the cranks of a crank shaft are expressed in degrees of a circle; if, for instance, the cranks project from opposite sides of the shaft so that they

are a half revolution apart, it is called a 180-degree crank shaft.

The outer ends of the crank arms, which correspond to the cranks of a bicycle, sup-

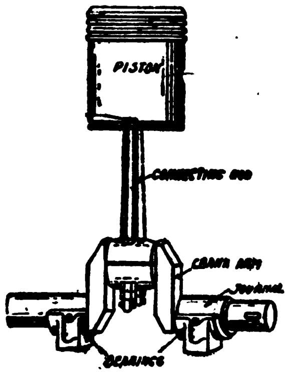


Fig. 5.—One-throw Crank Shaft.

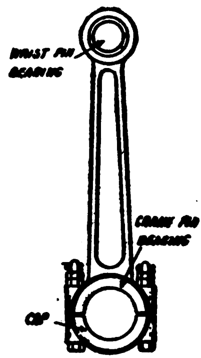


Fig. 6.—Connecting Rod.

port the **crank pin**, which may be likened to the pedal, and to this the large end of the **connecting rod** is attached, the small end being connected to the piston. The connecting rod must be of great strength, tough but not brittle, and is made of steel or bronze.

The piston is a trifle smaller than the bore of the cylinder, and its length is usually

greater than its diameter. It is hollow, with one end closed, the closed end being that against which the pressure is exerted. A **wrist pin** passes through it, and through the small end of the connecting rod, to enable the

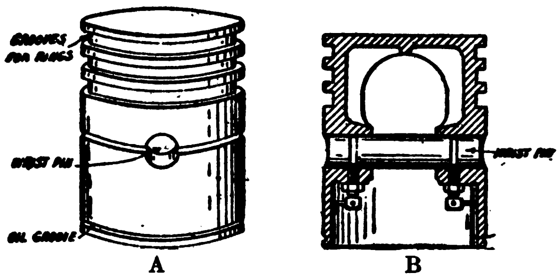


FIG. 7.—A, PISTON; B, PISTON IN SECTION.

latter to swing from side to side in following the turning of the crank shaft. A tight joint is maintained between it and the cylinder walls by cast-iron **piston rings**, which are of square or rectangular cross-section, split so that they may spring open, and fitted into grooves cut around the piston. They are of such shape that their tendency to expand keeps them pressed against the cylinder

walls, but being split, their elasticity prevents their binding; they fit the grooves snugly, and while they may move freely in them, they hold the pressure from escaping. The number of rings varies with the design of the engine, but the most usual arrangement is three to a piston, placed around the upper end.

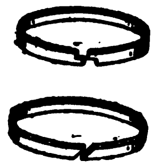


FIG. 8.—PISTON RINGS.

The cylinder should be of the highest grade of cast iron, with the smoothest possible surface for the piston to slide against.

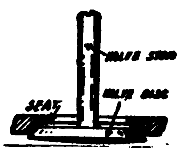


FIG. 9.—CONICAL VALVE SEAT.

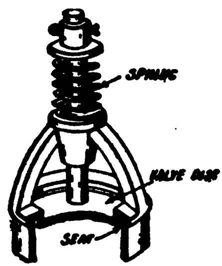


FIG. 10.—AUTOMATIC INLET VALVE IN CAGE.

The **valve** openings, or **seats**, are circular, and are usually made slightly funnel shaped,

the **disks** that cover them being slightly conical to fit. The large end of the funnel is toward the combustion space, so that when the disk is lifted from its seat it moves inward. Valves are held against their seats by coil springs that surround the valve **stems**, which are rods extending from the center of the disks, and there are two methods by which they are opened. In an **automatic valve**, the spring that holds the disk against its seat is weak, and the higher pressure outside of the cylinder during the suction stroke draws the disk away from its seat against the pressure of the spring. The valve remains open until the pressure in the combustion space is about equal to that outside, when the spring draws the disk back to its seat, to which it is held as long as the pressure inside is higher than that of the atmosphere. This arrangement is only possible for inlet valves, and is now rarely used, for exhaust valves, as well as inlet valves, are **mechanically operated**; that is, they are

opened and held open by a mechanism driven by the crank shaft, in the form of a **cam.** A cam can best be described as a " wheel with a hump on it," or, in other words, it is a piece of metal mounted on a shaft, cylindrical in form except for one portion, which projects farther from the shaft than the rest. The cam revolves with the shaft, and the projection, called the **nose,** will displace anything resting against it. The illustration shows a cam in three positions of its revolution, with the end of a valve stem resting against it—the roller being attached to the stem to reduce the friction. The valve stem is held in **guides,** so that the only movement it may have is up and down; when the cam revolves, the nose lifts the stem and opens the valve, holds it open as long as the flat end of the cam is under the steam, and when the nose passes from under, the valve is drawn to its seat by the spring.

The moment at which an automatic valve opens is governed partly by the tension of

its spring; if it is too strong, greater pressure will be required to open it, and it will close sooner than if the tension is light. Accurate adjustment of this spring is necessary in order that the charge may enter the com-

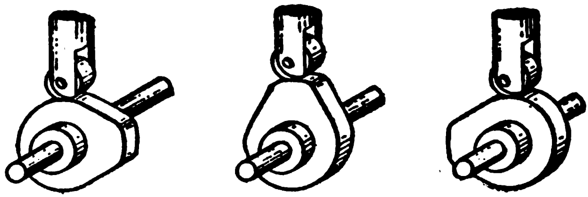


FIG. 11.—CAM ACTION.

bustion space without delay, and continue to enter as long as possible. The opening and closing of mechanically operated valves depend on the shape of the cam, and not being affected by the more or less uncertain action of a spring, they are more positive in action.

The **cam shaft** on which the cam is mounted is driven by the crank shaft, but as the valve opens but once during two revolutions, the cam shaft revolves at half speed, making one revolution while the crank shaft

makes two. This is done by means of **gears.**

If two gears running together, or in mesh, have the same number of teeth, they will make the same number of revolutions, but if one has twice as many teeth as the other, the smaller will revolve twice while the larger revolves once. As the cam shaft must revolve but once while the crank shaft revolves twice, its gear must have twice the number of teeth as the gear on the crank shaft. The cam shaft is also called the **secondary,** or **half-time shaft,** and the gears that drive it the **two-to-one gears.**

It is quite usual for the cam shaft to be driven by a chain instead of by gears, and Figure 12 shows two arrangements of chain-driven cam shafts. The chain drive has the advantage of being noiseless.

In some designs of engines, the nose of the cam bears directly against the valve stem, but it is more usual to place a **valve-lifter rod,** or **push rod,** between them, the cam act-

ing on the rod and lifting it, and that in turn lifting the valve stem. When the nose of the cam is not acting on the stem or rod, there must be a small space between them, for if the stem or rod rests firmly against the cam

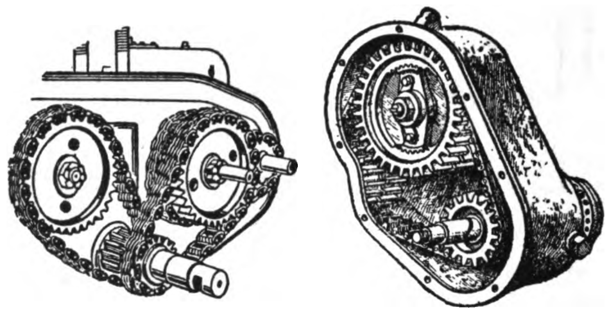


FIG. 12.—CHAIN DRIVE FOR CAM SHAFTS.

at all times, the valve disk might be prevented from seating firmly. The space is left between the stem and lifter rod, the spring acting only on the stem.

The valves may open into the cylinder in a variety of ways; both may be in one pocket, or one may be in a pocket and the other in the head, or each in a separate pocket, or both in the head. Seven arrangements of the

valves are shown in Figure 13. All of these are in common use, but the most popular is probably that shown in the third sketch, in which the valves are side by side in a single

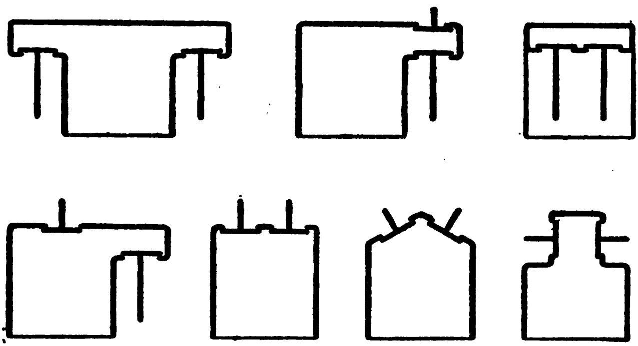


FIG. 13.—SEVEN ARRANGEMENTS OF VALVES.

pocket; a cylinder of this type is called an **L-head.** When the valves are in separate pockets on opposite sides, as shown in the first sketch, the cylinder is called a **T-head.**

When valves are set in the cylinder head, as shown in the second, fourth, fifth, sixth and seventh sketches, they are operated by means of **rocker arms,** or else the cam shaft

is placed above the cylinders instead of below them.

Valves of the kind described are known as **poppet valves**, and for many years nothing else was used. Their operation is satisfactory, but when worn they are inclined to be noisy. In order to eliminate noise from this source, valves of the **sleeve** type have been produced, and a sleeve valve engine is illustrated in Figure 14. It consists of a stationary cylinder containing two movable cylinders open at both ends, like pieces of pipe, and called the **outer sleeve** and the **inner sleeve**. These sleeves fit snugly, and are arranged to slide up and down in the cylinder. Inside of the inner sleeve is the piston, which is of the usual construction.

There **are** slots or **ports** cut part way around the upper part of the cylinder, one on each side, for the inlet and exhaust. Each of the sleeves has similar slots, and the action of the engine brings the sleeve slots in line with the cylinder ports, first on one side

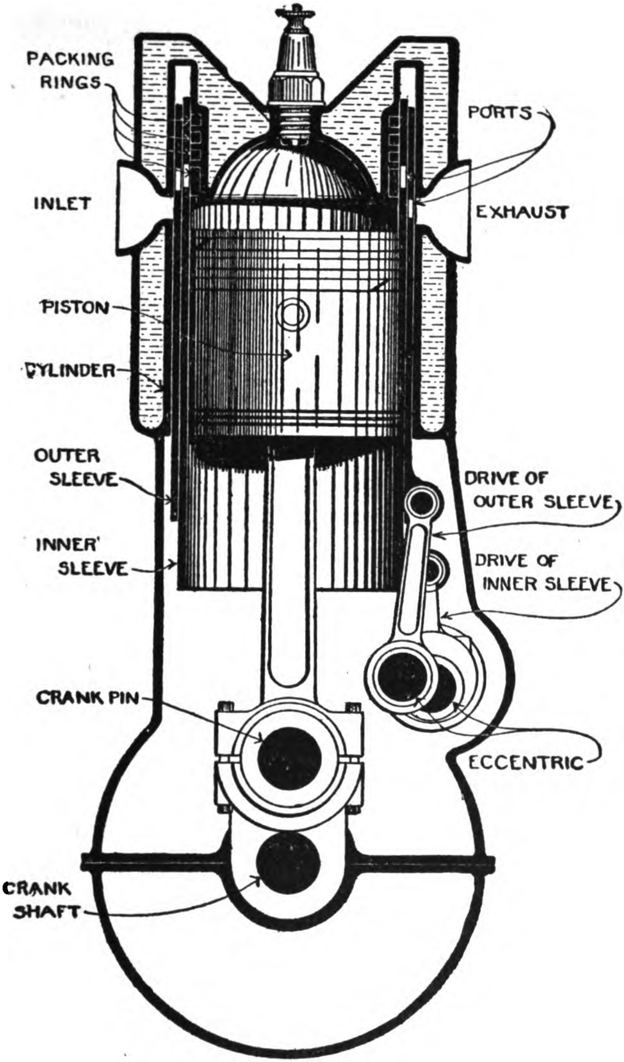


Fig. 14.—Sleeve Valve Engine.

and then on the other. Openings are thus provided by which the fresh mixture may enter and the burned gases may escape. During the compression and power strokes the sleeves cover the ports.

The cylinder head is so shaped that the sleeves may move up into a channel in it, and a tight joint is maintained by **packing rings**, which are similar to piston rings. Pressure is thus prevented from leaking during the compression and power strokes. The movement of the sleeves into the channel protects the edges of the slots from the intense heat developed during the power stroke.

The sleeves are driven by short connecting rods operated by **eccentrics** mounted on a shaft that corresponds to the cam shaft of a poppet valve engine.

Figure 15 shows the positions of the sleeves during the four strokes of the cycle. Each sleeve makes one upward and one downward stroke while the piston makes

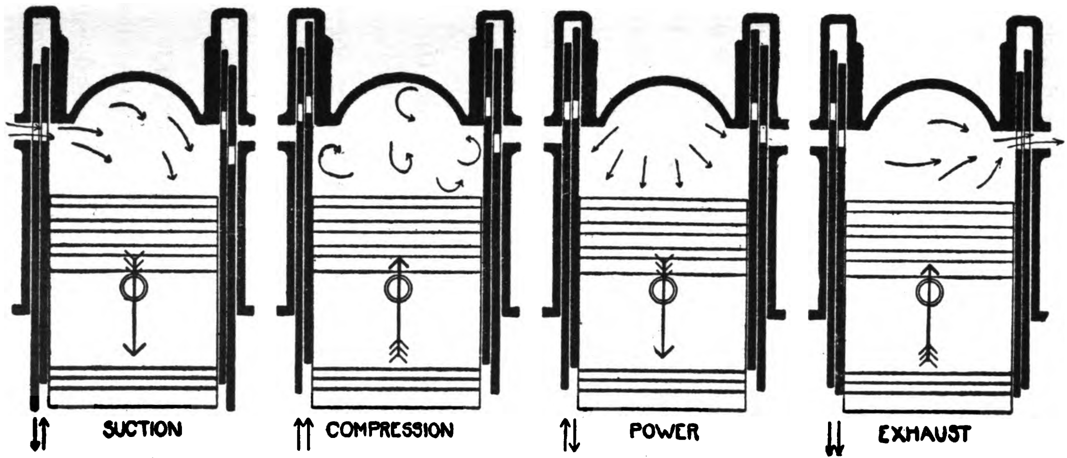


FIG. 15.—ACTION OF SLEEVE VALVE ENGINE.

four strokes; or, in other words, while the crank shaft makes two revolutions.

The sleeve principle was first used in the Knight engine, but it has been applied in a number of other designs.

If after the explosion the burned gases were permitted to escape directly into the open air from the cylinder, the effect would be the same as the firing of a gun, and for the same reasons. The pressure in the cylinder being higher than that of the atmosphere, the sudden expansion of the gases would produce a report, and as this would be most undesirable for an automobile, provision is made by which the gases are cooled and permitted to expand gradually, so that when they reach the open air they are at its pressure, or nearly so. This is done in the **muffler**, or **silencer**, to which the **exhaust pipe** conducts the products of combustion. The muffler consists of a series of chambers of different sizes, one inside of the other; the gases pass from the smaller to the larger, ex-

panding as they go, until from the largest they should escape without noise, having lost their heat and pressure.

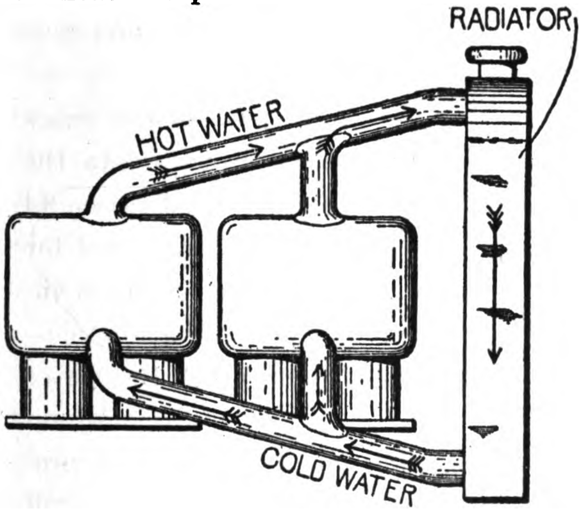


FIG. 16.—THERMO-SIPHON SYSTEM OF WATER-COOLING.

While the pressure exerted during the power stroke depends on the heat of the gases, and it is necessary to have the engine hot in order that there may be as little loss of heat as possible, the temperature must not be permitted to rise to the point at which the lubricating oil would burn. Lubricating oil

for gasoline engines is made to stand high heat, but if heated beyond its limit it will burn, and then, besides the loss of its property of lubrication, a deposit of carbon, hard or gummy, will form, fouling the combustion space or piston rings, and interfering with the operation of the engine. Overheating is prevented either by circulating water through channels surrounding the combustion space, or by directing a blast of air against it.

The channels, called **water jackets**, provided for the circulation of the water, are usually cast with the cylinder, or formed of sheet metal. Cool water enters at the bottom and escapes at the top, absorbing heat during its passage. Of the two systems of keeping the water in circulation, the most usual consists of a rotary pump, which forces the water through the jackets and then to a **cooler**, or **radiator**, which is so placed that it is exposed to the air currents set up as the car moves. In order to cool the water, the

radiator must have a large surface exposed to the air, and the water must pass through it in small streams. The early types con-

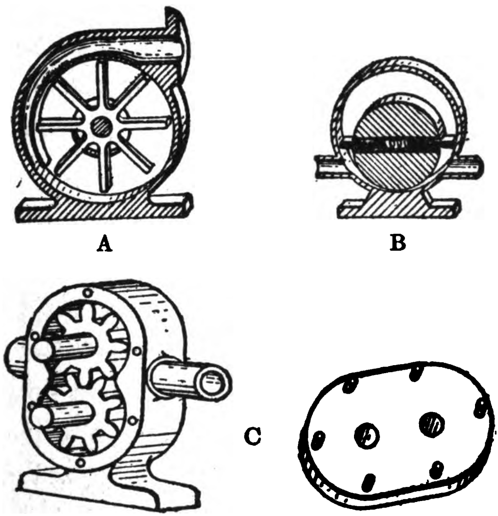


Fig. 17.—A, Centrifugal Pump; B, Valve Pump; C, Gear Pump and Cover.

sisted of coils of small copper tubing, on which were strung disks of copper, the water flowing through the tubing, and the disks absorbing its heat and giving it up to the air, but these are being abandoned in favor of **cellular** or **honeycomb** radiators. These

types, which are usually placed at the extreme front of the car, are made up of a

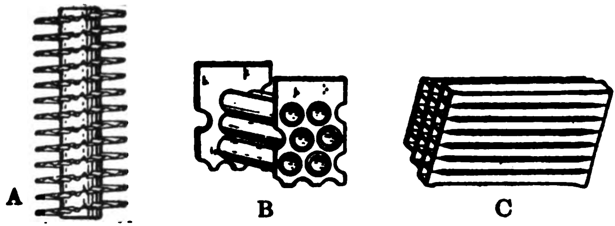


FIG. 18.—RADIATOR CONSTRUCTIONS. A, spiral flange (water passes through the tube); B, cellular, and C, honeycomb (air passes through the tubes; water passes through the tubes).

great number of short lengths of small tubing, in any one of several shapes, placed side by side, and held together either by plates or by soldering their ends.

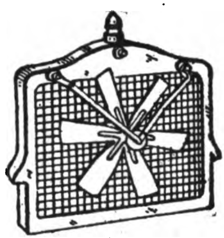


FIG. 19.—RADIATOR AND FAN.

The heated water enters at the top of the case in which the tubes are contained, and flows to the bottom, finding passages between the tubes, while the air passes through, being assisted by a fan driven by the engine.

The second system of keeping the water in circulation follows the principle that heated

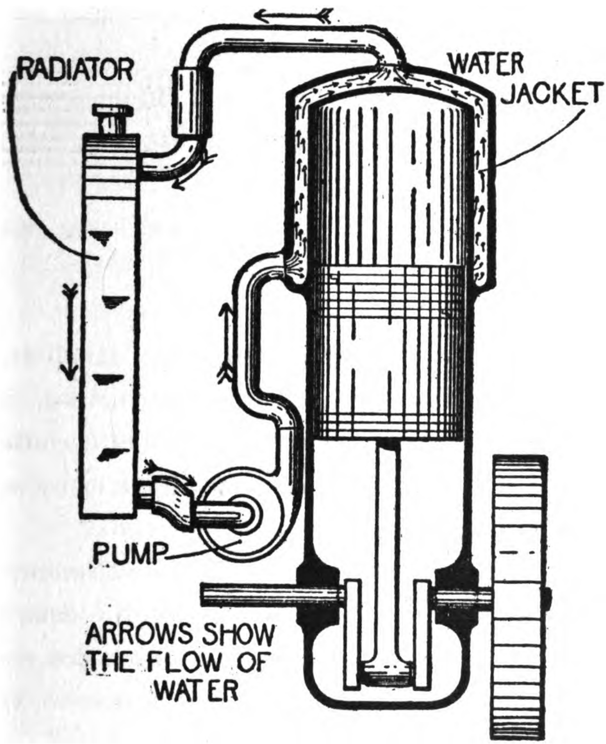


Fig. 20.—Force System of Water-cooling.

water tends to rise, its place being taken by the cooler water that tends to sink. This,

called the **thermo-siphon** or **gravity** system, requires all of the parts and connections to be large and completely filled with water. The water in the jacket rises as it absorbs heat from the cylinder walls, and flows out to the radiator, which it enters at the top. Its place in the jacket is taken by the cooled water from the bottom of the radiator, and this circulation continues, being more rapid as the difference in temperature between the heated and cooled water increases. It is naturally not so rapid as circulation that is forced by a pump, and more liable to become inoperative by the clogging of the pipes, jacket, or radiator.

Of the methods of increasing the surface of a cylinder in order to cool it by a blast of air, the most usual is to cast it with flanges that project from all parts of the combustion space. These become heated as the temperature of the cylinder walls increases, and the air that is blown against them carries off the heat. Other methods consist of setting pins

or copper strips into the cylinder walls, of such form that the air current strikes a surface composed of points, by which the heat easily passes to the air. Another system consists of surrounding the combustion chamber with a jacket open at the bottom, air being drawn through it from the top by a powerful blower or by a suction fan.

Other things that are necessary for successful air cooling are large valves by which the hot gases may be quickly discharged when their period of usefulness is ended, and small cylinders rather than large, as the heat from small quantities of gases may be carried off more quickly than from large.

The lubrication of a gasoline engine must be carefully looked after, as on its thoroughness depends the continued delivery of power. The most usual method of lubricating the piston and cylinder walls is to keep the crank case filled with oil to such a point that the end of the connecting rod dips into it in turning. This spatters the oil to all

parts of the crank case, and a portion is caught in a groove cut around the lower end of the piston. The inward movement of the piston spreads the oil on the cylinder walls, and it is distributed around the piston rings, so that they move easily in their grooves. As the oil is used up, it is replaced from a **lubricator** so that a constant level is maintained, and this operates either by gravity, or by a small force pump driven by the engine, or by the maintaining of pressure in the oil tank.

Mechanically operated or pressure lubricators supply oil to all parts of the engine, and as the quantity passed to each bearing is adjustable, a feed may be maintained that is exactly suited to the requirements.

The bearings of an automobile operate under such widely different conditions that one kind of lubricant will not be suitable for all. The maker of the car has tested the different oils, and it is advisable to follow his instructions on the brand and grade most suitable

for each bearing, rather than to try experiments. The Lubrication Table on pages 326 and 327 gives the kind and quantity of lubricant most suitable to the work performed by each bearing.

CHAPTER III

ENGINE BALANCE

A DRAWBACK to the use of reciprocating engines is that the weight of the piston and connecting rod in sliding first one way and then the other produces great vibration, and that the crank shaft in bringing these parts to a stop at each end of the stroke is subjected to violent shocks that in time wear it loose in its bearings. With internal-combustion engines this vibration, and the shock on the crank shaft, are greatly increased by the intensity with which the pressure is exerted.

Engines with one cylinder may be balanced to some extent by the use of counterweights attached to the crank shaft, and by the use of so heavy a fly wheel that its momentum produces a comparatively steady movement; but a perfect absorption of the

vibration would require the engine to be run at a constant speed, which is not possible with those used on automobiles.

In two-cylinder engines the vibration may be reduced by so arranging the parts that the pistons slide in opposite directions, the weight of one being balanced by that of the other. This plan is used in engines of the **horizontal double-opposed** type, which is considered to be the most satisfactory for low powers. The cylinders are horizontal, with their open ends toward each other, the crank shaft lying between them. The crank shaft is **two-throw**, 180°; that is, there are two pairs of crank arms, projecting from opposite sides of the shaft, so that they are a half revolution apart.

Two cylinder engines are also built with vertical cylinders, and are of two types, according to the construction of the crank shaft. In one, the crank shaft is 180°, and in the other both pairs of crank arms project from the same side of the shaft so that the

crank pins are in line, this being called a 360° crank shaft.

In the 180° type one piston moves up as the other moves down, so that they balance, but it results in the power strokes occurring in both cylinders during one revolution of the crank shaft, with no power during the revolution that follows.

To understand the reason for this, the order in which the events of the cycle occur must be recalled, and it must be remembered that of the four strokes of the piston during which they are performed the two outward strokes are inlet and power, and the two inward strokes compression and exhaust. If the piston of a two-cylinder vertical engine (Fig. 21) is moving downward on the power stroke, piston No. 2 will be ascending, and the only events that can then be performed in its cylinder are compression or exhaust. If performing compression, it will move under power during the next stroke (the other half of the revolution), No. 1 then exhaust-

ing (Table No. 1). This brings the two power strokes in one revolution, and during the next revolution there will be no power stroke, for No. 1 will be performing suction and compression, and No. 2 exhaust and suction.

If, as shown in the second table, No. 2 is moving upward on exhaust while No. 1 moves down under power, its previous stroke, the first half of the revolution, will have been the power stroke, and the same condition will exist of two power strokes occurring in the same revolution.

In either case the balance of the moving parts is offset by the irregular production of power, which produces bad results in the setting up of strains in the engine, and the uneven running of the car.

In two-cylinder vertical engines with 360° crank shaft (Fig. 21) the pistons move up and down together, which of course results in bad balance. In this arrangement, however, the applications of power may be

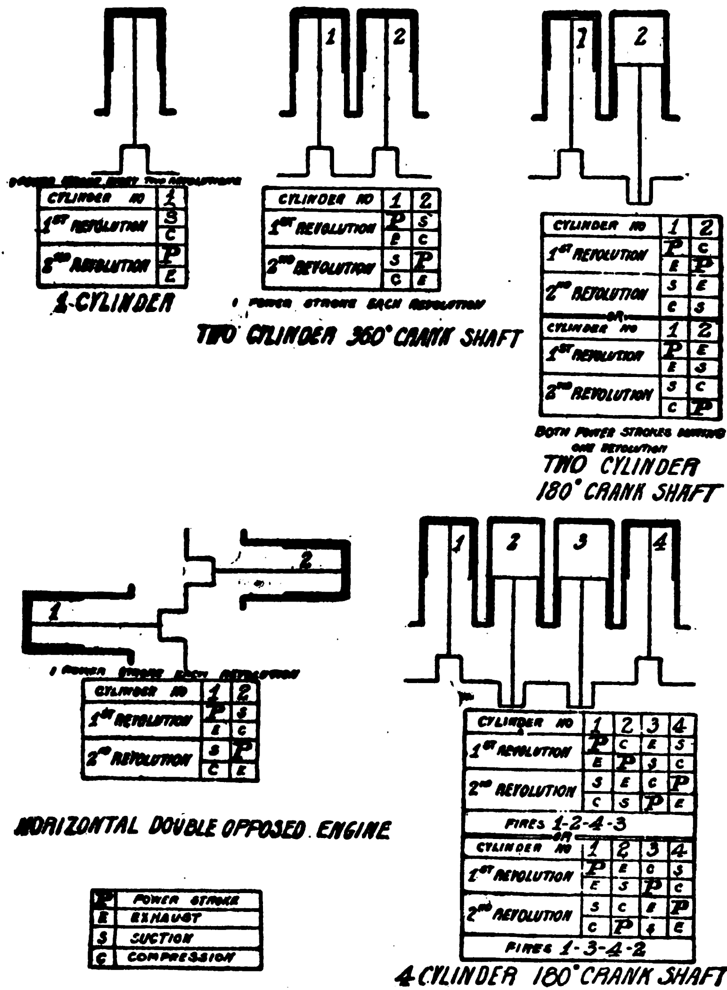


FIG. 21.—ENGINE ARRANGEMENTS SHOWING ORDER OF FIRING.

evenly spaced, for as the piston in cylinder No. 1 moves downward on the power stroke, piston No. 2 moves in the same direction, and may make either the inlet or power stroke. If it makes the inlet stroke, it must move inward before it can again move outward on the power stroke, and there will be an interval of one stroke between the power strokes of the two cylinders. To have the power strokes in the two cylinders occur together, as suggested as the alternative, would obviously give bad results in the great strain imposed on the crank shaft, the weight of the fly wheel that would be necessary to carry two pistons through three dead strokes, and the jerky running of the car.

The defects of two-cylinder vertical engines with either design of crank shaft outweigh any possible advantage of that construction, and the horizontal double-opposed type, in evenly occurring power strokes, mechanical balance, and simplicity, is in

almost universal use for cars of low power.

A two-cylinder engine does not require so heavy a fly wheel as a one-cylinder engine in proportion to the power delivered, because there is a power stroke every revolution instead of in alternate revolutions, and the parts must be carried over only one dead stroke instead of three. Similarly, the fly wheel of a four-cylinder engine may be still lighter, for in that type there are two power strokes in every revolution, with no dead strokes. At the same time, it is not possible to dispense with it entirely, for the pressure acting on the piston at the beginning of the power stroke falls rapidly as the piston moves before it, and the momentum by which the fly wheel tends to revolve at a constant speed steadies and smooths what would otherwise be a jerky motion.

The crank shaft of a four-cylinder engine is 180°, four-throw, with the two end cranks projecting in the opposite direction to that

of the two inside cranks. This arrangement is used in preference to having the cranks project alternately; that is, the first and third to one side and the second and fourth to the other, because of economy in manufacturing, and because practice has shown that it results in less vibration in the running of the engine.

This construction of the crank shaft does not permit the power strokes to occur in rotation, cylinder No. 2 following No. 1, and then Nos. 3 and 4, for it has been explained that when cranks are 180° apart the power strokes occur during one revolution, and that when 360° apart there is a dead stroke between the two power strokes. Cranks 1 and 2 are 180° apart, as are 3 and 4, and also 2 and 4, but 2 and 3 are 360°; that is, their crank pins are in line, which is also the case with 1 and 4. The power stroke in cylinder No. 2 may follow that in cylinder No. 1, but must be followed by that in cylinder No. 4, as that is 180° away from No. 2, and No. 3

comes last, being 180° from No. 4. The succession in which the power strokes occur, called the **firing order,** is thus 1, 2, 4, 3, and this is arranged for by the setting of the valves and the timing of the ignition.

This firing order was used for the first four-cylinder automobile engines, but it has lately been suggested that the firing order 1, 3, 4, 2 shows advantages in the reduction of strains and vibration, and it is being adopted.

CHAPTER IV

SIX- AND EIGHT-CYLINDER ENGINES

A FOUR-CYLINDER engine runs more evenly than an engine with one or with two cylinders, and is able to run at a lower speed, because there is a lesser interval between power strokes. To follow this principle still further, and to enable the engine to deliver power even when running at a very low speed, the six-cylinder engine has been introduced, and has come into very wide use.

In a four-cylinder engine, a power stroke in one cylinder is completed before the following cylinder begins to deliver power; in a six-cylinder engine, the power stroke of a cylinder begins before the completion of a power stroke by the preceding cylinder, and its own power stroke is only partly completed when

the following cylinder begins to deliver power. By this overlapping of the power strokes, the crank shaft is under a nearly continuous application of power, and its rotation is, therefore, very steady and uniform.

To obtain this effect, the crank shaft must be so made that when one piston is at the end of a stroke, another piston is part way up on a stroke, and still another is part way down. The appearance of a crank shaft of this sort is shown in Figure 22. It will be seen that the cranks project from the shaft in pairs, each pair being one-third of a revolution, or 120°, from the remaining pairs. Thus, if the pistons of the cranks that are numbered 3 and 4 in the drawing are passing the top of the stroke, the pistons of cranks 2 and 5 will be one-third of the way up, and the pistons of cranks 1 and 6 two-thirds of the way down. When pistons 2 and 5 have reached the top of their stroke, pistons 3 and 4 will have moved two-thirds of the way to the bottom, and pistons 1 and 6 will have

passed bottom dead center and moved through one-third of the upward stroke.

If piston 1 is considered to be moving down on a power stroke, we can consider that the

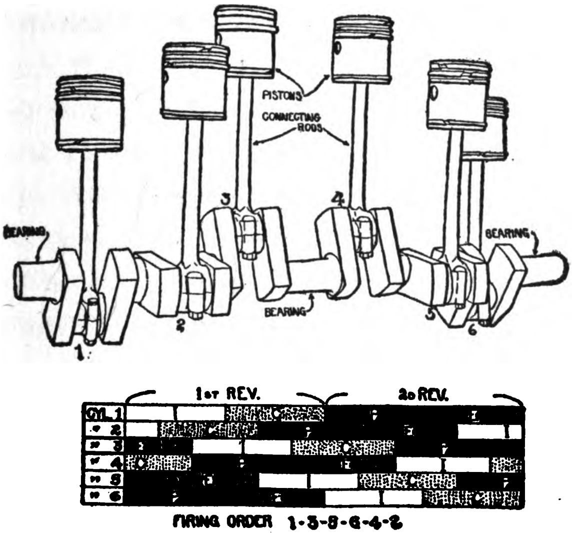


FIG. 22.—CRANK SHAFT OF SIX-CYLINDER ENGINE.

next piston to move under power is number 3, and the drawing shows that piston 3 will begin to deliver power when piston 1 is only two-thirds of the way through its power stroke. Piston 5 will be the next to deliver

power; as shown in the drawing, it is one-third of the way up at the instant when piston 3 is at top center. Thus, when piston 5 reaches top center and begins to deliver power, piston 3 will be two-thirds of the way down.

For the first one-third of a stroke, the crank shaft will be acted on by power from two cylinders; for the second one-third of the stroke only one cylinder will be acting, while for the last one-third of the stroke the crank shaft will again be receiving power from two cylinders. As the power strokes overlap, it goes without saying that the other parts of the cycle overlap also, and in the same manner; this is shown in the diagram, Figure 22.

With a four-cylinder crank shaft only two firing orders are possible, but with a six-cylinder crank shaft there is a much larger number. The usual firing orders, however, are 1-3-5-6-4-2, 1-5-3-6-2-4, and 1-4-5-6-3-2.

Aside from the crank shaft, six-cylinder engines are identical in parts and construc-

tion with four-cylinder engines, but are half again as long and have a correspondingly greater complication.

In the case of eight-cylinder engines, which are widely used for aviation and to some extent for automobiles, the cylinders are arranged in two rows of four cylinders each, the rows being side by side and inclined to each other at an angle of 90°. The eight connecting rods are attached to a single crank shaft, which is similar in arrangement to the crank shaft of a four-cylinder engine; that is, it has four throws, projecting in pairs 180° apart. An eight-cylinder engine is no longer than a four-cylinder engine with cylinders of the same size.

The application of power by an eight-cylinder engine is continuous, for a piston is only halfway through a power stroke when the succeeding cylinder begins to deliver power, and in this is found the reason for the extreme flexibility and smoothness of this type of engine.

CHAPTER V

CARBURETION AND GASOLINE FEEDS

PURE gasoline vapor will not burn, and in order to render it inflammable it must be combined with oxygen. The simplest manner of effecting this is to mix air with it, and when the correct proportions are obtained, the oxygen supplied by the air will be sufficient to result in the complete combustion of the gasoline vapor, without a surplus of either of the ingredients. This mixing is called **carburetion**, the air being said to be **carbureted.** A correct proportion of gasoline vapor and air results in rapid combustion; an excess of air makes combustion slower, and excess of gasoline vapor prevents the combustion from being complete, a residue of carbon remaining. The correct proportions of air and gasoline vapor are obtained by the use of a device called a **car-**

buretor, which is connected to the combustion chamber by the **inlet pipe,** and in such a manner that everything entering the combustion space by the inlet valve must first pass through it.

Liquid gasoline is led to the carburetor from the supply tank, and the air enters it when the pressure in the combustion space is reduced by the piston in making the inlet stroke. The speed with which the air flows through the carburetor depends on the extent to which the pressure is reduced, and the gasoline vapor that is required to form a mixture of the correct proportion must be maintained in accordance with it. While there are various classes of carburetors, practically all that are used for automobile engines are of the **float-feed** type; that is, the supply of gasoline is maintained by a **float,** just as water tanks are kept filled to a desired depth by a hollow metal ball that floats on the liquid and controls the valve by which the water enters.

The principal parts of a float-feed carburetor are the **float chamber** and the **mixing chamber**, the gasoline flowing from the supply tank to the float chamber, and from there to the mixing chamber, where it is combined with the air. The gasoline flows out of the float chamber through a small pipe, the end of which, called the **spray nozzle**, projects into the mixing chamber so that the current of air rushes past its tip (Fig. 23). When the inlet stroke is not being performed, and there is no air passing through the mixing chamber, the float in the float chamber keeps the gasoline at such a level that it stands just below the tip of the spray nozzle. In this condition the gasoline in both the float chamber and the spray nozzle is under atmospheric pressure; but when the pressure in the combustion space is reduced as the piston makes the inlet stroke, the pressure in the inlet pipe and mixing chamber is also reduced, and the gasoline will be forced out of the spray nozzle by the higher pressure in

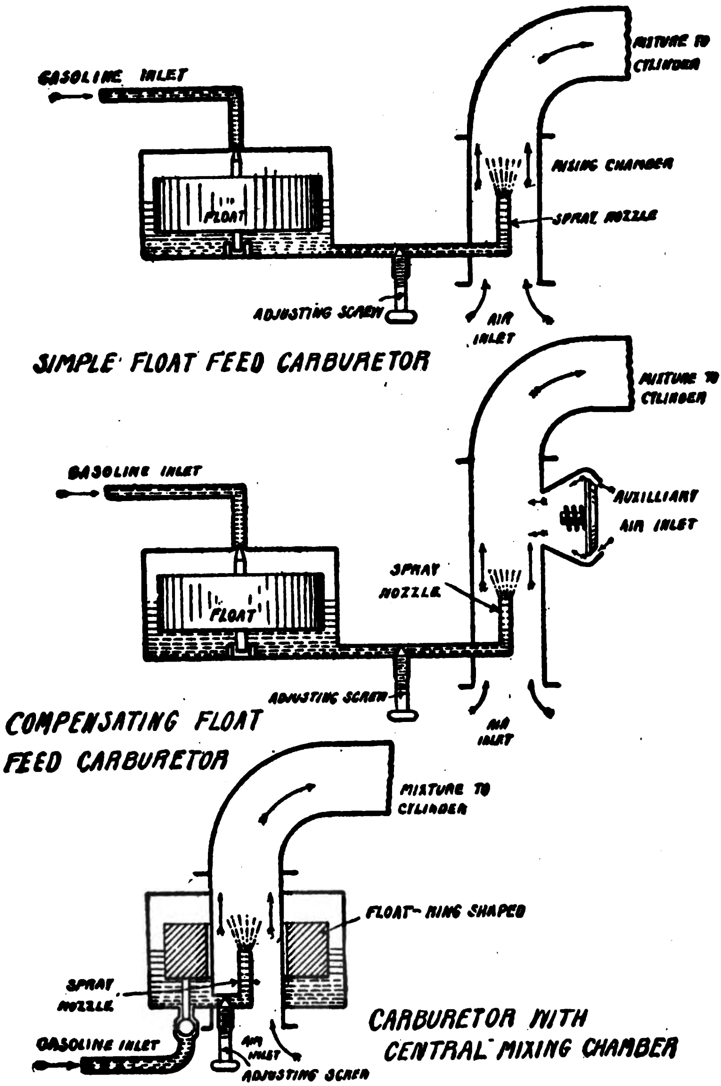


Fig. 23.—Carburetor Principles.

the float chamber. The passage in the tip of the spray nozzle is small, and the gasoline is broken up into fine drops as it spurts out, and in this condition is partly absorbed by the air and partly carried into the cylinder. By regulating the amount of gasoline that may pass out of the spray nozzle, it may be adjusted to the volume of air flowing through the mixing chamber, so that any desired proportion may be obtained.

If the engine were to be run at a constant speed, the relative pressures on the gasoline in the float chamber and spray nozzle, and the quantity of gasoline forced out of the spray nozzle, would remain in correct proportion to the volume of air; but as the engine of an automobile is run at greatly varying speeds, the pressure in the mixing chamber is not constant, but varies to correspond. If the piston makes fifty inlet strokes a minute, the reduction of the pressure in the mixing chamber is more gradual than would be the case with the piston making two hundred

inlet strokes a minute. The more rapidly the pressure is reduced, the greater will be the effect of the unchanging atmospheric pressure in the float chamber, and the more gasoline will be forced out of the spray nozzle. This will result in the presence of too much gasoline in proportion to the air, giving a mixture that is **too rich.** It is therefore necessary to provide an arrangement by which the pressure in the mixing chamber will not be changed as the speed of the engine varies, and this is accomplished by the **auxiliary air inlet,** which is closed when the engine runs slowly, but opens to correspond with increasing speed (Fig. 23). The faster the engine runs, the more the auxiliary air inlet will open, to admit a correspondingly greater amount of air to prevent the pressure in the mixing chamber from being reduced below the point at which the required amount of gasoline is forced out of the spray nozzle.

The most rapid combination of the gasoline and air is secured by breaking the gaso-

line up into fine spray as it leaves the nozzle. In order to break the gasoline into fine particles, the tip of the spray nozzle is made with a fine opening, and often forms the seat for the gasoline adjusting valve, which is a needle-pointed rod that is screwed in or out to reduce or enlarge the opening; a further breaking up results from the placing of a metal cone, or the end of a rod, in such a position as to be struck by the gasoline as it flows out.

A carburetor with an auxiliary air inlet is provided with two points of adjustment, to control the flow of gasoline from the float chamber to the spray nozzle, and to govern the admission of the auxiliary air. The flow of gasoline must be just sufficient to carburet thoroughly the air passing through the mixing chamber when the engine runs at low speed, and the auxiliary air inlet must open to correspond with increasing speed, to admit sufficient air to keep the pressure reduced to proper proportions.

The auxiliary air inlet may be operated either by the reduced pressure that permits the atmospheric pressure to open a valve, or

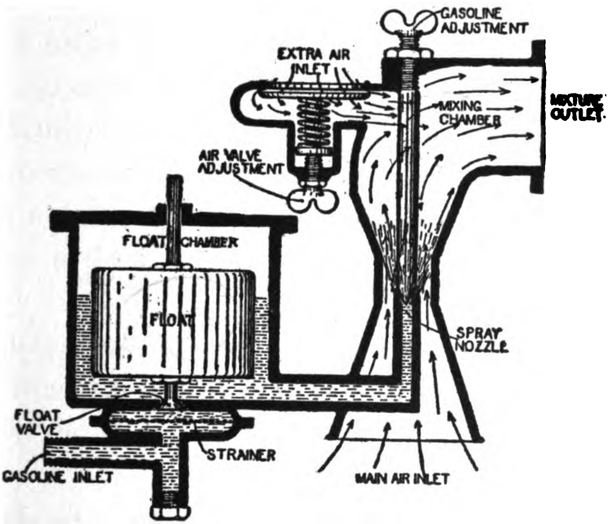


FIG. 24.—COMPENSATING CARBURETOR, SIDE FLOAT CHAMBER.

by the governor of the engine, which opens the inlet as the speed increases, and closes it on slowing down. The first of these two types, called a **compensating carburetor,** is in most general use for automobiles, and is

sufficiently satisfactory, but is not as accurate as the mechanically controlled type, which acts independently of pressure, and exactly according to the speed of the engine.

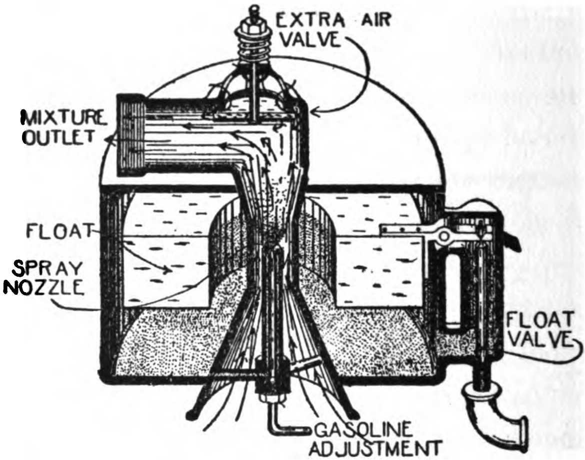


FIG. 25.—COMPENSATING CARBURETOR, CONCENTRIC FLOAT CHAMBER.

Carburetors may be divided into two types, according to design: those in which the float and mixing chambers are side by side, and those in which the mixing chamber passes through the center of the float chamber (Figs. 24 and 25). The former is along

the lines of the first forms of float-feed carburetors, and the latter is of more recent design, its object being a more compact device, and one that is not affected by a change of level when the car is on a hill. Both have advantages and disadvantages, and the use of one as against the other is optional and a matter of opinion.

The carburetors illustrated are not of any particular makes, and are intended to show principles rather than construction.

In carburetors with a side mixing chamber the float is usually a metal box, the joints of which are as far as possible proof against leakage. Guides prevent it from having any but an up-and-down motion, and in thus moving it controls the gasoline inlet valve by a rod attached to it, or by a separate valve stem. When the level in the float chamber drops as the gasoline runs out of the spray nozzle, the float sinks, and the float drops from its seat. This admits gasoline from the supply tank, and the float in rising on it

draws the valve to its seat, and shuts off the flow. The gasoline adjusting valve is in the spray nozzle. The main or initial air inlet is in the top, the air entering through the upper part of the mixing chamber. The auxiliary air inlet is a simple valve, opening inward, and held against its seat by a coil spring, the tension of which is adjustable. The pressure in the mixing chamber being reduced in accordance with the increasing speed of the engine, the valve is opened more and more as the atmospheric pressure against the outer surface of the valve overcomes the tension of the spring.

In carburetors with central mixing chamber the float is ring- or horseshoe-shaped, and usually made of cork, well varnished to prevent the absorption of the gasoline. The air enters at the bottom, passing directly to the mixing chamber. The auxiliary air inlet is at the top, and is of the arrangement already described. The mixture passes out at the side, and may be controlled by a **throttle,**

which may be a damper arrangement, or other device by which the quantity passing to the combustion space is at the will of the operator.

The float and mixing chambers of a mechanically operated carburetor are the same as in the side-float chamber type, the difference being in the control of the auxiliary air inlet (Fig. 26). This consists of a tube attached to the mixture outlet, within it sliding another tube moved by the governor as that expands or contracts with the speed of the engine. There are openings in the sides of both tubes, but when the sliding tube is at its inmost position these are not in line, and consequently are closed. When the governor acts with increased engine speed, the sliding tube is drawn out, and one or more openings come into line, air entering through them to the mixing chamber. The faster the engine runs, the larger become the openings, and in consequence the greater is the amount of air that they admit. The illustration shows the

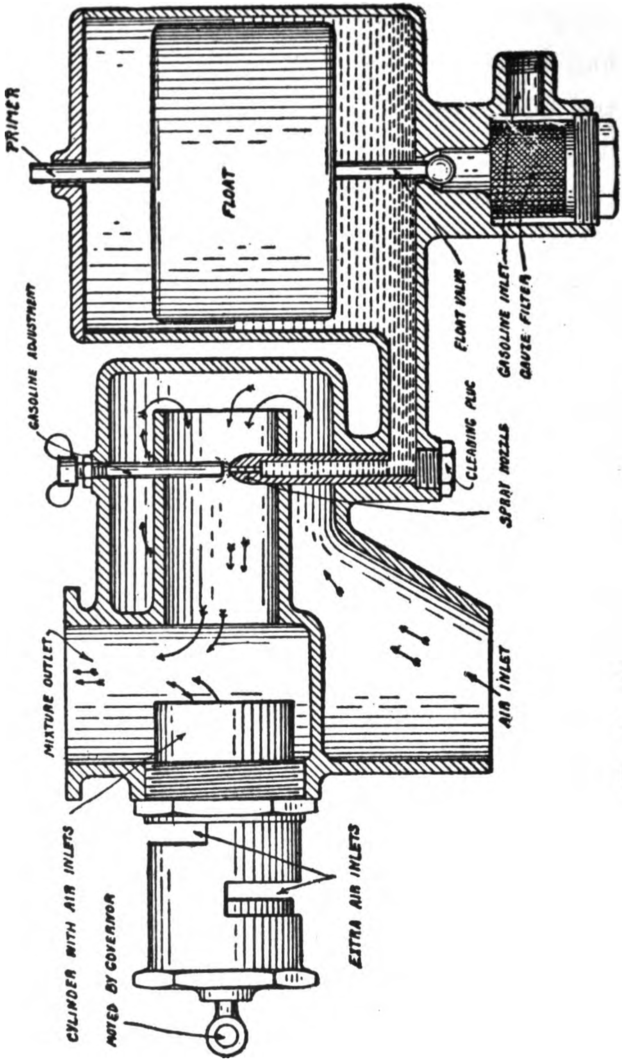


FIG. 26.—MECHANICALLY CONTROLLED CARBURETOR.

ball type of gasoline valve, the ball on the end of the valve stem being drawn against its seat as the float rises.

While these types are in practically universal use for automobile engines, there are other methods by which the proportions of the mixture may be maintained. In one form the gasoline drops on a funnel made of fine wire gauze, which is placed in the mixing chamber in such a manner that the air in entering passes through it. The liquid forms a film over the gauze, and is picked up by the air, as it is in a condition that permits it to evaporate rapidly. In surface carburetors air is forced through the gasoline tank, or through an absorbent material soaked with gasoline, and becomes thoroughly saturated. This mixture is then thinned with pure air until the desired proportion is obtained, when it passes to the combustion space. The objections to these forms arise from the clogging of the parts with the impurities present in gasoline, and while they give excellent re-

sults when new, they deteriorate rapidly and present such resistance to the flow of the air current that they become useless.

Practically all the carburetors on the market are combinations of a few forms of float valves, auxiliary air inlets, and spray nozzles. In addition to the forms shown in Figures 24 and 25, the most usual float valves may be seen in Figure 27. In the first two types shown in this diagram, the float valve stems are separate from the floats, and are sufficiently heavy to shut off the flow of gasoline by their weight. In the third type, the gasoline enters the float chamber from the top, and as the valve stem is attached to the float, the rising of the float results in the shutting off of the gasoline. The fourth type is in use on carburetors with central mixing chambers, the float being hinged to one wall of the float chamber. The loose valve stem is supported by the hinge, and rises to a seat in the valve when the gasoline is at the proper depth on the float chamber.

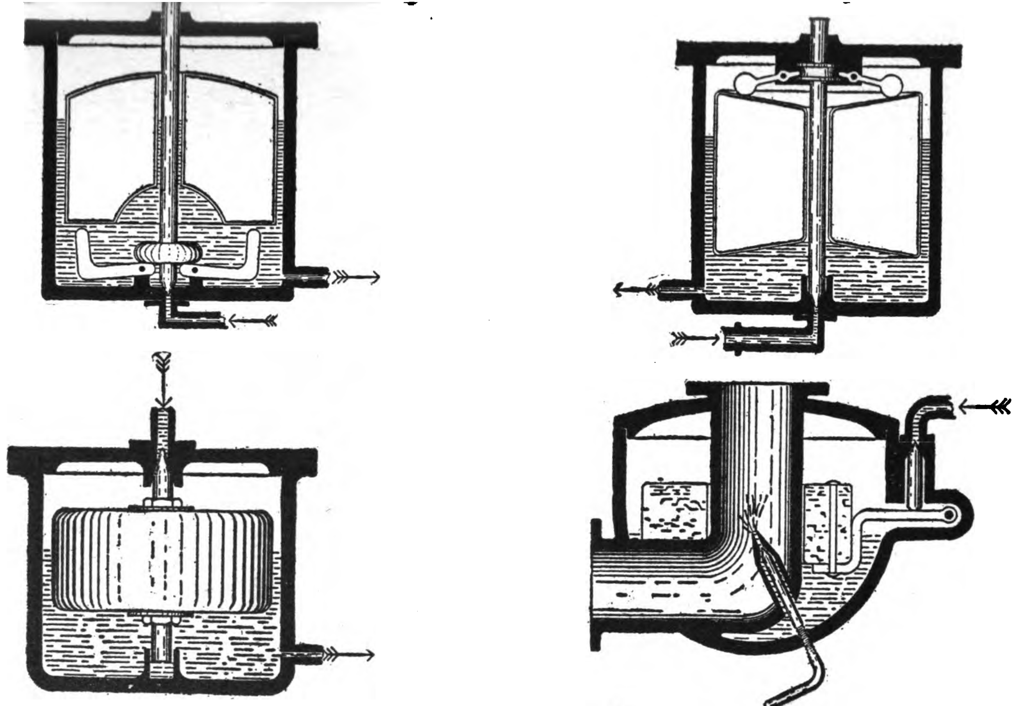


FIG. 27.—TYPES OF FLOAT VALVES.

Figure 28 illustrates the most usual forms of auxiliary air inlets. In the first type, the valve disk slides on the valve stem, and enlarges the size of the main air inlet. All of the air thus passes the spray nozzle. In the second type, the inlet for the auxiliary air is separate from the main air inlet, the two currents meeting in the mixing chamber, and the extra air diluting the rich mixture that is formed at the spray nozzle. This action is more correct in theory than that of the preceding type, and better practical results are obtained from it. These air valves are defective in opening and closing too abruptly, and in tending to vibrate rather than to remain open a fixed distance. The air inlet illustrated in the fourth diagram was designed to overcome these faults. When the engine is not operating, the air inlets are closed by a hollow piston that is held up by a spring. The upper part of the piston rod carries a metal disk that is attached by a flexible leather washer to the walls of an up-

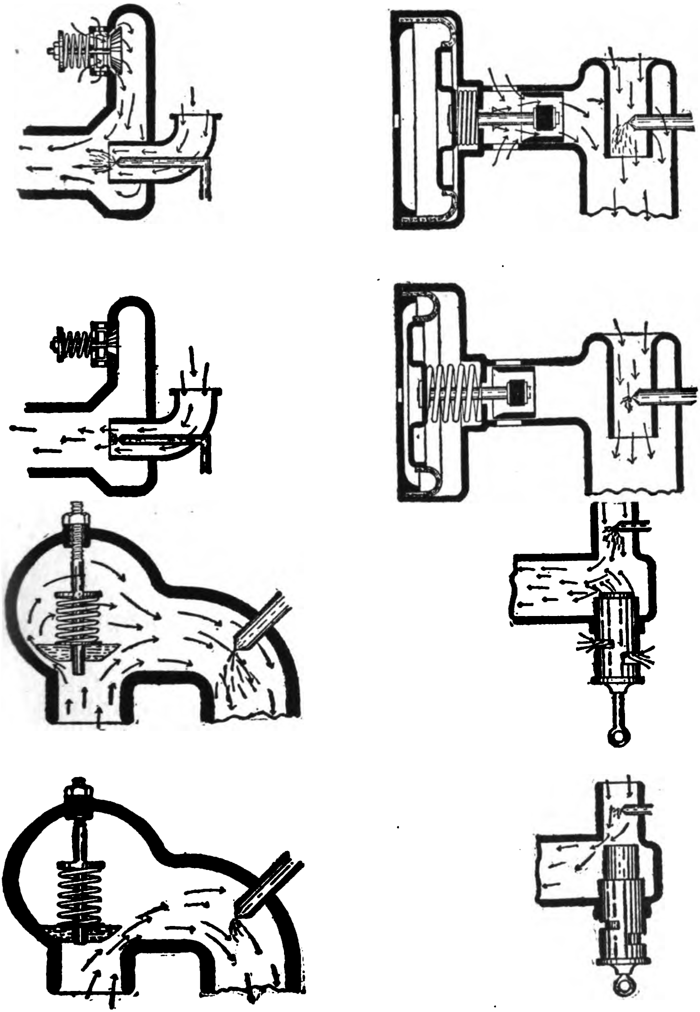


FIG. 28.—TYPES OF AUXILIARY AIR INLETS.

per chamber. The portion of the chamber above the disk is tightly closed, except for a small hole in the cover that provides the only communication between the atmosphere and the air confined in the chamber. When the engine runs at speed, the atmospheric pressure against the upper side of the disk is greater than the pressure against the lower side, and the disk is therefore forced downward against the action of the spring. The movement of the disk moves the piston, and as this latter slides downward it uncovers the openings and admits air. The small size of the opening in the cover prevents air from entering or leaving the chamber above the disk rapidly, and the movement of the piston is therefore steady and free from jerks. The third diagram illustrates two positions of a mechanically operated auxiliary air inlet, controlled by a governor.

There are two methods of supplying the carburetor with gasoline. Of these the most usual is the **gravity feed**, in which the tank

is placed at a higher level than the carburetor, so that the gasoline flows down to it. The tank is usually placed under the seat, and the piping so arranged that the carburetor is the lowest point of the system. This method of feeding is satisfactory if the tank can be placed sufficiently above the carburetor to have the flow unaffected by an ordinary hill, but if it is not so placed, a steep ascent may tilt the car to such an extent that the carburetor is above the level of the gasoline in the tank, in which case the flow of course ceases.

The **pressure feed**, which is in general use on high-grade cars, operates through the maintenance of pressure in the supply tank, the gasoline being forced out without regard to gravity. The tank is tight, so that the pressure cannot escape, and is connected by a long pipe of small diameter either with the combustion space of one of the cylinders or with the exhaust pipe, so that the pressure of the burned gases is maintained in it. As

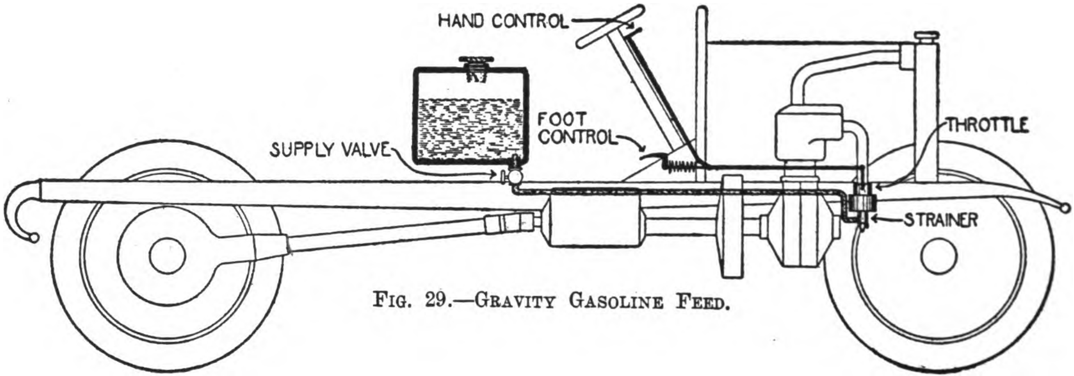


Fig. 29.—Gravity Gasoline Feed.

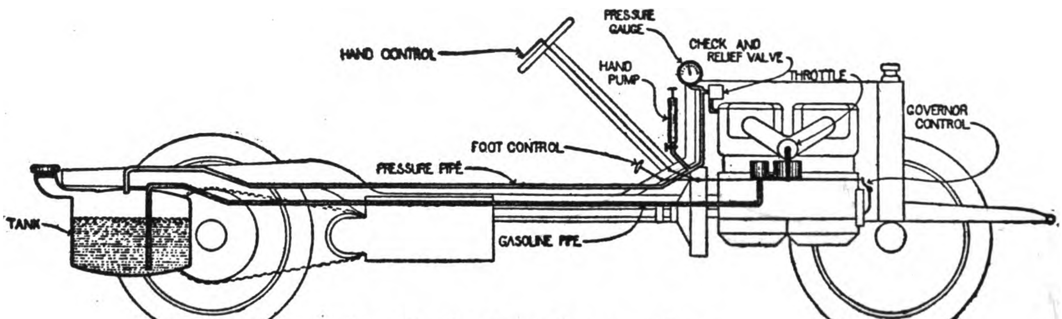


Fig. 30.—Pressure Gasoline Feed.

the pressure cannot exist until the engine is running, a hand air pump is usually provided, by which a sufficient pressure may be produced in the tank to force out enough gasoline for starting. It is necessary to use as long a pressure pipe as possible, in order to prevent the possibility of flame passing through it to the supply of fuel, a long pipe, exposed to the air, cooling the gases to such an extent that they cannot ignite the gasoline.

The pressure pipe is always fitted with a **check and relief valve,** which acts as a safety valve in preventing the pressure in the tank from reaching a point at which the joints might be strained, and also retains the pressure which would otherwise escape when the engine stops. A check and relief valve is shown in Figure 31. It is placed in the pressure pipe, the gas or air that supplies the pressure acting in the direction of the arrows. The gas can lift the check valve and flow past it, but cannot return because the

valve will come to a seat and close the passage. The relief valve is held on its seat by an adjustable spring, and controls an opening to the outer air. When the pressure

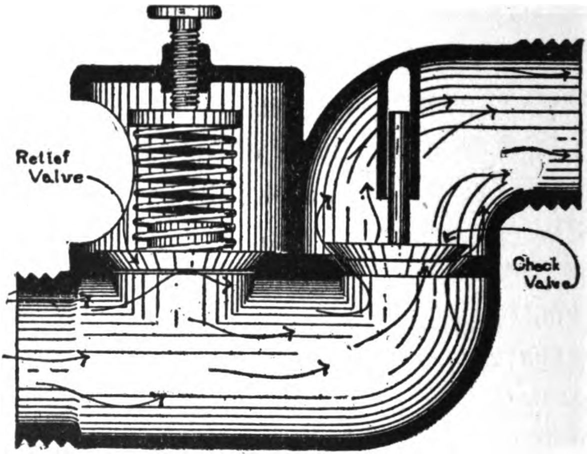


FIG. 31.—CHECK AND RELIEF VALVE.

against the under side of the relief valve becomes greater than the pressure of the spring, the valve will be forced open. It may be adjusted to retain any desired pressure, and will " blow off " when the pressure rises above this point.

In some cars an auxiliary gasoline tank is

provided on the dash, being fed by pressure from the main tank, and from which gasoline flows to the carburetor by gravity. The short distance of this tank from the carburetor and its elevation prevent the possibility of the flow being stopped by any tilting of the car short of an upset.

Because of the liability of the presence of water in the gasoline, as well as dirt and grit, the gasoline line should be fitted with a **strainer**, or **trap**. This may be in any position, but it is usual to have it close to the carburetor, if not built into it. The simplest strainer consists of a number of thicknesses of fine wire gauze, so arranged that it may be easily taken out for cleaning. This will separate the dirt from the gasoline, and water may be caught in a trap, which is a pocket where the water, being heavier than the gasoline, may settle and be drawn off.

CHAPTER VI

IGNITION PRINCIPLES

A GASOLINE engine derives its power from the heat that is produced by the burning of the charge of mixture. Each charge that is taken into the cylinder is capable of producing a certain quantity of heat, but the power that the engine will develop from the charge will depend upon how much of the heat is employed in the driving outward of the piston. Some of the heat must inevitably be lost. The exhaust gases are hot, and the water in the cooling system becomes heated; the heat that thus passes away is not available for the production of power. All that the engine designer, builder and user can do is to keep these losses as low as possible.

In order to make the engine run under the best possible conditions, the mixture should

be set on fire and made to give up all of its heat when the piston is at the top of the compression stroke and ready to move down on the power stroke. The charge would then be most highly compressed, and the heated gases would exert the greatest possible pressure in striving to expand. This cannot be done, however, for there is no method by which the entire charge can be ignited and made to burn as instantaneously as would be necessary.

The setting on fire, or **ignition**, of the mixture is done by passing an electric spark through it. This spark ignites the particles of mixture with which it comes into contact, and the flame thus started spreads through the entire charge. The flame spreads very rapidly, but the high speed at which the piston moves requires the allowance of a certain time between the instant when the spark passes and the instant when the entire charge is on fire.

The condition to be sought is to have the

piston at top center of the compression stroke at the instant when the entire charge is in flame, for the greatest quantity of heat is then produced, and the piston is consequently under the greatest possible pressure. If there were some way to set fire to all of the particles of mixture at the same time, so that the entire charge would burst into flame, ignition should be made to occur when the piston is at top center. As there is no way of doing this, and as it is necessary to allow time for the flame to spread through the mixture, ignition is made to occur while the piston is on the compression stroke; the piston will thus be moving upward while the flame is spreading, and will reach top center at the instant when all of the mixture is in flame.

In consequence of this, some of the heat will be wasted, for it will be produced while the piston is moving upward on the compression stroke. The result of producing heat at this time will be, in the first place, to check

the movement of the piston, and, in the second place, to leave less heat to act against the piston during the power stroke.

If ignition is caused to occur when the piston is at top center, the piston will have moved part way down on the power stroke before the whole charge is on fire. As the space above the piston in which the heat is acting is then large, the pressure on the piston will be small, and, as a result, the engine will deliver very little power. By causing ignition to occur while the piston is still on the compression stroke, so that the whole charge becomes ignited as the piston reaches top center, the space above the piston will be small; the pressure on the piston will consequently be great, and the engine will deliver full power. If ignition occurs too early in the power stroke, full pressure will be produced before the piston reaches top center, and will be great enough to check the piston or even to stop it.

The point in the stroke at which ignition

should occur depends principally on the speed at which the engine runs, but is also affected by the quality of the mixture. The time that must elapse between the passing of the spark and the instant when all of the mixture is on fire does not change with the speed of the engine. In consequence the point in the compression stroke at which the spark passes must change in accordance with changes in engine speed, in order that combustion may be complete when the piston reaches the end of the stroke. As an illustration, the spark must occur later in the stroke when the piston is moving slowly than when it is moving fast. Thus, when an engine is being started, the spark should not occur until the piston is practically at top center, for the piston will then be moving so slowly that there is ample time for the flame to spread throughout the mixture before the power stroke is started. When the engine speed increases, the spark must be made to occur earlier in the stroke.

When the spark is produced late in the stroke, it is said to be **retarded**; and it is **advanced** by being made to occur earlier in the stroke.

A mixture that is correct in its proportions burns more rapidly than one that is too rich or too poor. An improperly adjusted carburetor requires the spark to be advanced more than would be necessary with a proper mixture, and thus makes the engine lose power. The proper advance to give the spark can only be determined by experience, and it is not unusual to have an engine injured by being run for long periods with the spark advanced too much or too little. In the first case, combustion will be complete before the piston reaches top center, and the crank shaft and connecting rod bearings will be unduly worn by the excessive strain; in the second case, the piston will have moved downward on the power stroke for a considerable distance before combustion is complete, and the engine will become overheated.

Small engines may frequently be operated with **fixed ignition**; that is, the point in the stroke at which ignition occurs cannot be varied. This point will be sufficiently close to top center to prevent the danger of a "kick-back" on starting, but at the same time will be far enough advanced for general operation. On engines with small and compact combustion spaces this system is entirely practical (provided a proper ignition system is used) for the time required for the spread of the flame is of little moment.

In some cases, the use of fixed ignition may not permit the engine to produce its greatest output, but the system is none the less advantageous in simplifying the engine control. It is the tendency of inexpert drivers to advance the spark too greatly, which results in the rapid wear of the engine parts; for this reason, fixed ignition is of particular advantage for commercial cars.

A great number of methods of igniting the mixture have been tried, but the system that

has come into universal use on automobile engines is known as the **jump spark**, or **high tension**, system. In this, an electric current is caused to jump between two pieces of metal located in the cylinder, and the spark that is formed is sufficiently hot to set on fire the particles of mixture with which it comes into contact.

The jump spark ignition system is made in many forms, but all have certain features in common. These are the **generator** that produces the electric current that forms the spark, the **timer** or **circuit-breaker** that controls the instant at which the spark occurs, and the **spark plug** at which the spark is formed.

In order to understand the action and relation of these parts, and to keep the system in proper order, it is necessary to know something of the principles of electricity and of electric currents; a brief explanation is thus given.

Electricity is understood to be a natural

force that exists in everything, but in its normal condition it is at rest, and is not noticeable. To make use of electricity it must be set in motion, and it is moving electricity, or, in other words, an **electric current,** that operates an electric light or an electric motor, or that produces an ignition spark.

An electric generator is nothing more nor less than a device to make electricity move, and thus to produce an electric current. A generator sets the electricity in motion by raising its pressure. Similarly, steam is caused to flow by raising its pressure, and it flows from the boiler, where the pressure exists, to the outer air, where the pressure is low. A steam engine is made to run by placing it in the path of the current of steam, and requiring the steam to flow through it in order to get to the open air.

An electric generator has two connections, or **terminals,** at one of which the pressure is high, while at the other the pressure is low. If there is a path between the two, an electric

current will flow from the high pressure terminal to the low pressure terminal as long as the generator is operating. These terminals are given names by which they may be distinguished, the high pressure terminal being called the **positive** or **plus** (+) terminal, while the low pressure is called the **negative** or **minus** (—) terminal; the current always flows from positive, or plus, to negative, or minus.

All electrical apparatus: motors, lamps, measuring instruments, bells, and so on, are so constructed that they operate when an electric current flows through them. To make them work, they are placed in the path of an electric current, which must flow through them in order to get from the positive terminal of its generator to the negative terminal.

The path provided for the current is made of metal or of carbon, for electricity will flow over these materials without difficulty; copper wire is generally used for the path, because electricity will flow over copper more

easily than over any other common material. The path cannot be made of rubber, mica, wood, china, cloth or string, for these materials will not permit the current to flow over them; they are known as **insulators**, or

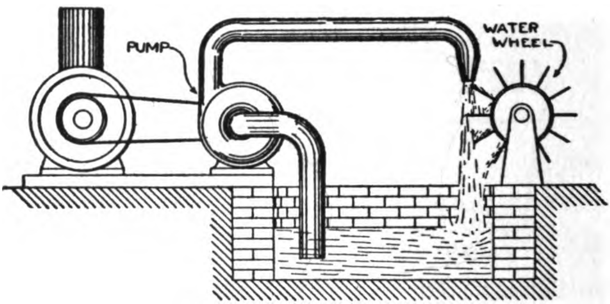


FIG. 32.—PRINCIPLE OF CURRENT FLOW.

non-conductors, and are used to keep the current on its proper path.

Figure 32 is a diagram showing a water pump driven by an engine; the pump raises water from a tank and forces it through a pipe. In flowing out of the end of the pipe the water strikes a water-wheel, and makes it revolve; after passing the wheel the water returns to the tank, from which it will

again be pumped through the pipe. By exerting pressure, the pump sets the water in motion, and the moving water does work in making the wheel revolve.

Electricity acts in a similar manner; the

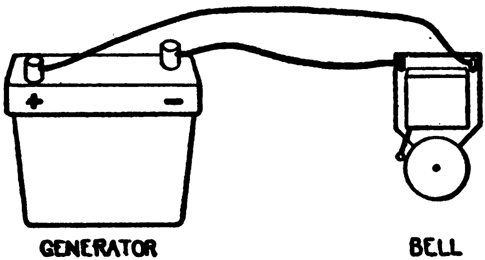


FIG. 33.—ELECTRIC CIRCUIT.

generator starts it in motion, and the moving electricity, or electric current, operates the bell, or lamp, or whatever apparatus may be in its path, finally returning to the generator (Fig. 33). If the current is prevented from returning to the generator by the breaking of a wire, or for any other reason, the flow of current stops.

The path provided for the current is called the **circuit**; if the current can leak from the

circuit and return to the generator without doing the work that it is expected to do, the leak is called a **short-circuit.** It is apparent that short-circuits are wasteful, and that they should be prevented. The circuit is therefore **insulated**, or, in other words, the path is supported and surrounded by insulating material that will make leakage impossible.

Electric currents are measured very much as streams of water are measured; that is, a measurement is made of the pressure that forces the current to flow, and another measurement is made of the quantity of electricity that flows. It is the quantity of electricity that does work; the greater the quantity, the more will be the work done.

In order to make an electric lamp burn, a definite quantity of electricity must be forced through it, and in order that the required quantity may be forced through the lamp, it is necessary to have the electricity under equally definite pressure. This applies not only to lamps, but to all electrical apparatus.

For example, it will be noticed that a Bosch coil bears the mark "6 volts"; this indicates that in order to force through it the quantity of electricity necessary to make it work properly, the current must be under a pressure of six volts.

Electrical pressure is measured in **volts**, and the higher the pressure, or **voltage**, the greater will be the quantity of electricity that is forced over the circuit. A very low pressure will be sufficient to force a current over a circuit that is made of metal, but if the circuit has in it even a very small air space, as, for instance, the ends of two wires held close together, the pressure necessary to force the electricity over it will be many thousands of volts. Air is one of the best of insulators; that is, it presents very great resistance to the flow of current, and special apparatus is necessary to produce enough pressure to force the current through it.

The quantity of electricity that flows in a circuit is measured in **amperes**. The higher

the voltage, the greater will be the **amperage** of the current that is forced over the circuit.

If hot water is used in the pump shown in Figure 32, the pipe will become heated, and so will the air surrounding the pipe. When an electric current flows over a wire, it affects the air that surrounds the wire, for the air becomes charged with magnetism.

Everyone has played with a magnet, and knows that, while it has the ability to attract to it pieces of iron and steel, it has no effect

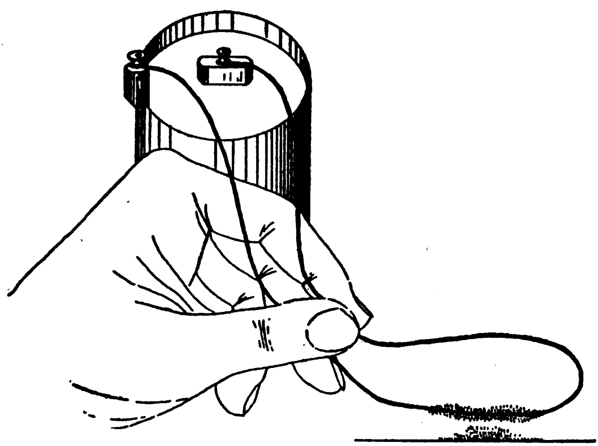


FIG. 34.—MAGNETISM FROM ELECTRICITY.

on copper, wood, rubber or any other material. A pile of iron filings may be stirred with a copper wire without being affected in the slightest degree, but if an electric current is passing through the wire, the filings will cling to the wire as if it were a true steel magnet. (Fig. 34.)

A piece of iron that is near a magnet will become magnetized itself, and will be able to attract other pieces of iron and steel, but it loses this ability when the magnet is removed. (Fig. 35.) This is one of the points of difference between iron and steel, for iron gains magnetism very easily, but cannot retain it, while

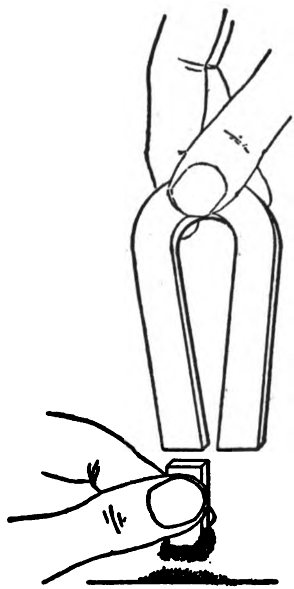


FIG. 35.—MAGNETIZING A PIECE OF IRON.

steel gains magnetism with difficulty, but retains it indefinitely.

If a wire through which an electric current is flowing is wound around an iron bar, the

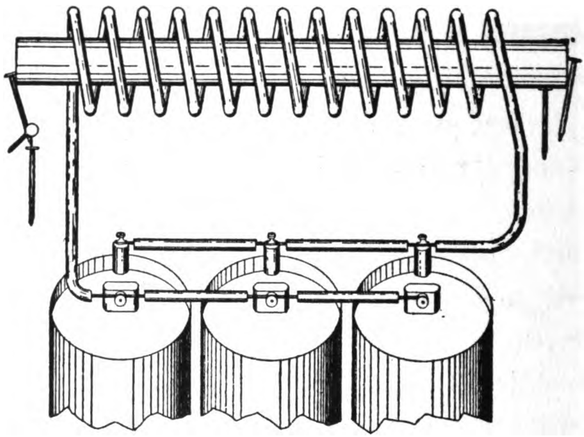


Fig. 36.—Magnetizing Iron by Electricity.

iron will become a magnet and will remain a magnet for just as long as the current flows. (Fig. 36.) The bar will lose its magnetism the instant that the current stops flowing.

Magnetism can thus be produced from electricity, and, conversely, electricity can be

produced from magnetism. Figure 37 shows an iron bar with a wire wound around one end, this wire being connected with a generator so that an electric current can be passed through it; around the other end of

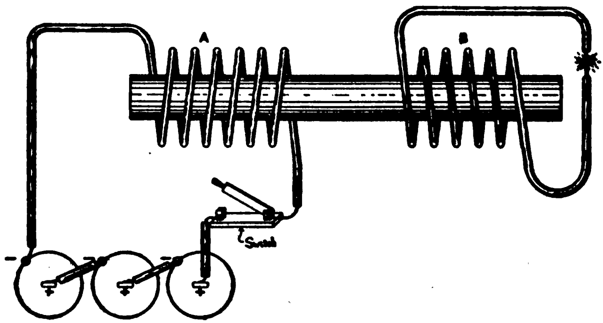


FIG. 37.—ELECTRICITY FROM MAGNETISM.

the bar is wound a second wire in no way connected with the first. When the current is not flowing, there will be no magnetism in the bar, but when the circuit is closed, the bar will become magnetized by the magnetism produced by the flow of current in the wire. The bar will begin to become magnetized the instant that the current starts

flowing, and its magnetism will get stronger and stronger until it reaches the greatest strength that can be produced by the quantity of current. The bar will remain magnetized as long as the current continues to flow, but the magnetism will die away very abruptly the instant that the flow of current stops.

If the current weakens, the strength of the magnetism will weaken also; any change in the strength of the current will be accompanied by a corresponding change in the strength of the magnetism of the bar.

Whenever the magnetism of the bar changes strength, an electric current will appear in the second wire, and the strength of this new current will be in accordance with the extent to which the strength of the magnetism changes. Every slightest change in the strength of the magnetism produces a current, and the current will be strongest when the change from weak to strong or from strong to weak is most abrupt.

When the circuit of the first wire is closed and the generator current starts flowing, the bar rapidly becomes magnetized to full strength, and remains at full strength while the current continues to flow; the new current will flow in the second wire while the change is going on, but the flow will stop the instant that the strength of the magnetism stops changing.

On the breaking of the generator circuit, the magnetism will die away very abruptly, and while it is dying the new current will again flow in the second wire.

It is thus seen that the new current is produced, or **induced**, only while the magnetism is changing strength. It makes no difference how the bar is magnetized; it may be magnetized by an electric current, as described, or by a steel magnet, or by any other method that will permit the strength of the magnetism to be changed.

The necessity for this explanation of magnetic principles becomes clear when it is un-

derstood that the ignition spark is always produced by magnetism, and that when a battery is used its current is required to produce magnetism, which in turn induces the current that forms the ignition spark.

CHAPTER VII

MAGNETO PRINCIPLES

IT is almost invariably the case that on automobile engines the ignition spark is produced by a generator called a **magneto.** This is a machine containing powerful steel magnets, with an iron bar that is arranged to revolve between the ends of the magnets in such a manner that it is continually being magnetized and demagnetized. The changes in the strength of the magnetism of the bar induce electric currents in a wire wound around it, and it is these currents that produce the ignition spark.

The revolving bar is called the **armature,** and its shape is shown in Figure 38. The only part to which attention need be paid is the **core;** the **heads** act to direct the magnetism to the core, and it makes no difference in the action of the magneto whether or not

they are magnetized. The heavy line in the diagram indicates the position of the wire; in an actual armature the amount of wire

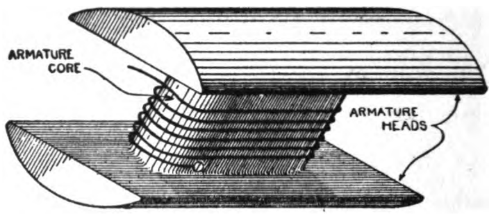


FIG. 38.—ARMATURE.

used will fill the entire space between the heads.

The flow of magnetism is indicated by the arrows in Figure 39, which is a diagram of the end of a magneto and of the armature; the armature is shown in four positions while making a half-revolution. In positions A, B and D, the magnetism, in flowing from one end or pole of the magnet to the other, finds its easiest path through the armature core, while in position C the easiest path is through the armature heads. It is in passing from one of these positions to another that

the magnetism of the armature changes strength, with the result that electric currents are produced in the armature winding.

In the following explanation, it must be borne in mind that magnetism alone will not

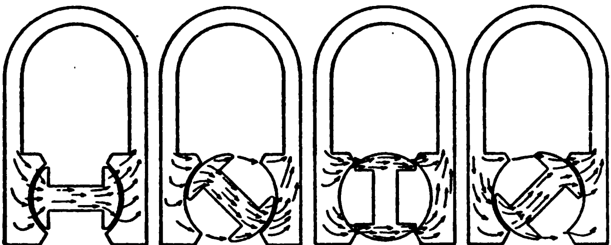


FIG. 39.—FLOW OF MAGNETISM IN ARMATURE.

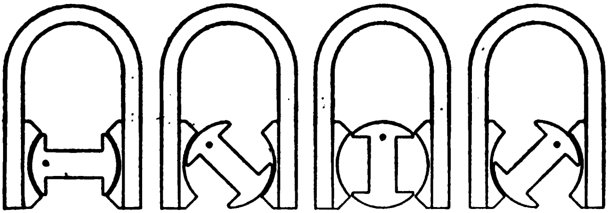
produce an electric current; it is necessary for the magnetism to be changing in strength. In order to produce a current that is sufficient to form an ignition spark, there must be a very considerable change in strength, and the change must occur abruptly.

When the armature is not revolving, no current is produced, for, while the core may

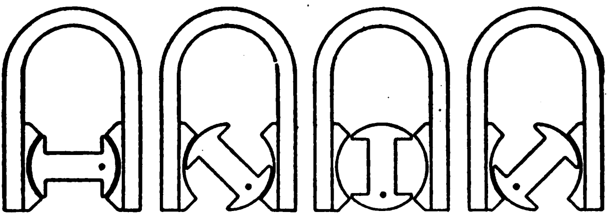
be magnetized, the magnetism is not changing its strength. When the armature is revolved, the magnetism of the core continually changes its strength, and twice during each revolution the strength changes completely, going from full strength to no strength and back again. The faster the armature is driven, the more abrupt these changes will be, and the currents produced at high speed will consequently be more intense than those produced at low speed.

Referring to Figure 40, which shows the positions of the armature during a complete revolution, the armature in position A is intensely magnetized, for practically all of the magnetism of the magnets then flows through the core. In position B, most of it continues to flow through the core, but it is beginning to find it easier to flow through the heads and across the air space. In position C the easiest path is through the heads, and the magnetism entirely abandons the core, which now has no strength. When the

armature moves from position A to position C, the magnetism of the core completely dies away, but it returns as completely when the



A. Mo. Current. B. Weak Current. C. Intense Current. D. Weak Current.



E. Mo. Current. F. Weak Current. G. Intense Current. H. Weak Current.

FIG. 40.—PRODUCTION OF CURRENT IN MAGNETS.

armature moves from position C toward position E. During the second half of the revolution there will be another complete change in strength.

When the armature passes from position H to position B, or from position D to position

F, there is only a slight change in the strength of the magnetism, and the current then produced will be too weak to form an ignition spark. When the armature passes from position B toward position D, or from position F toward position H, the change in the strength of the magnetism is very great; it is greatest as the armature passes over positions C and G, and it is then that the current is sufficiently intense to form an ignition spark.

In former types of magnetos the most intense spark was produced just as the armature left position C or position G. A spark could be produced at any point between positions C and D, and between positions G and H, but the closer the armature approached D and H, the faster it was necessary to drive it in order to obtain a sufficiently intense spark. The magneto was set in such relation to the engine crank shaft that the most intense spark occurred when the piston was on the compression stroke and approaching top

center; the spark was then fully advanced. When cranking the engine, or running it slowly, it would be necessary to produce the spark later in the stroke, or even at top center, to prevent back firing; by the time the piston reached top center, however, the armature would have moved from position C to position D, and would have to be turning at high speed in order to give a spark.

To make it easier to crank an engine, or to run it slowly, it is advantageous to have a magneto so constructed that it gives a spark at as low a speed in the fully retarded position as when fully advanced. In Bosch magnetos this is accomplished by means of extensions on the pole shoes, somewhat like broad teeth. This is shown in Figure 41.

In applying a magneto to an engine, it must be remembered that the engine requires a spark to be produced at a certain point in the stroke, and also that the magneto will give a spark at definite points in the rotation of the armature; clearly, then, the crank

shaft and the armature must run in such relation that the armature is giving a spark at the instant when the engine requires one.

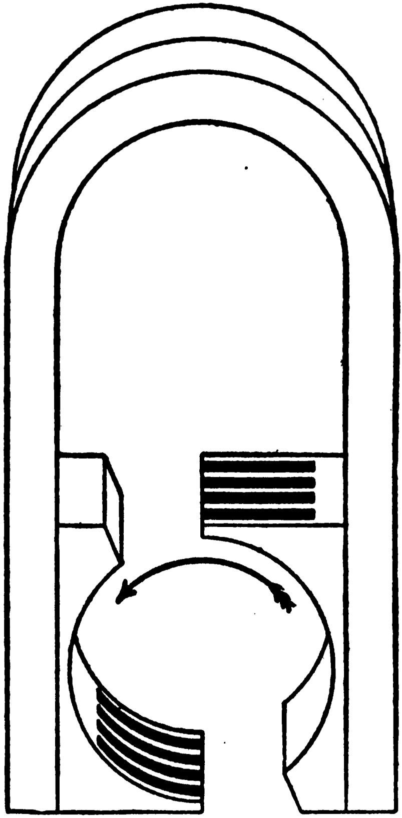


FIG. 41.—EXTENDED POLE SHOES OF BOSCH MAGNETOS.

A four-cylinder, four-cycle engine will require two sparks during each revolution of the crank shaft, and as a magneto will deliver two sparks during each revolution of the armature, it will be seen that for such an engine the armature must be driven at the same speed as the crank shaft. A 6-cylinder, 4-cycle engine requires three sparks during each revolution of the crank shaft; in producing three sparks the armature must make 1½ revolutions, and it is thus apparent that for such an engine the armature must be geared to run at 1½ times the crank shaft speed, or, in other words, it must make three revolutions while the crank shaft makes two.

A single cylinder 4-cycle engine requires but one spark during every two revolutions of the crank shaft. Theoretically, its magneto should be driven at one-quarter the speed of the crank shaft, so that it makes one-half of a revolution while the crank shaft makes two. Practically, this speed would be so slow that the magneto might not produce

a spark at the speed at which the engine is cranked, and the armature is therefore driven at one-half the crank shaft speed. The magneto is so arranged that it gives only one spark during each revolution, instead of two.

When a magneto is used on an engine with a number of cylinders it must be so arranged that it distributes its sparks among the various cylinders as required by the firing order, and this is done by a device known as a **distributor.** A distributor consists of a brush, usually in the form of a piece of carbon, that is attached to a revolving part of the magneto. As this brush revolves it comes into contact with one after the other of a series of metal blocks, there being one block for each cylinder. At the instant when the magneto is giving a spark, the brush will be in contact with one of the blocks, and the sparking current will pass from the armature to the brush, to the block, and to the cylinder where the spark is to be formed. By the time that the next cylin-

der requires a spark, the armature will have made one-half of a revolution, and the distributor brush will have moved to the next block.

In 4-cycle engines, the distributor makes one revolution to two of the crank shaft, no matter how many cylinders the engine may have; in other words, the distributor runs at cam shaft speed. In 2-cycle engines the distributor runs at crank shaft speed. The distributor is built into the magneto, and is geared to the armature shaft and driven by it. Diagrams of distributors for different numbers of cylinders are shown in Figure 42.

Ignition magnetos are further fitted with a device known as the **circuit breaker**, or **interrupter**, which is connected to the armature winding, and controls the instant at which the spark occurs. A circuit breaker consists of a block of metal carefully insulated from the metal of the magneto, combined with a lever that is so pivoted that it

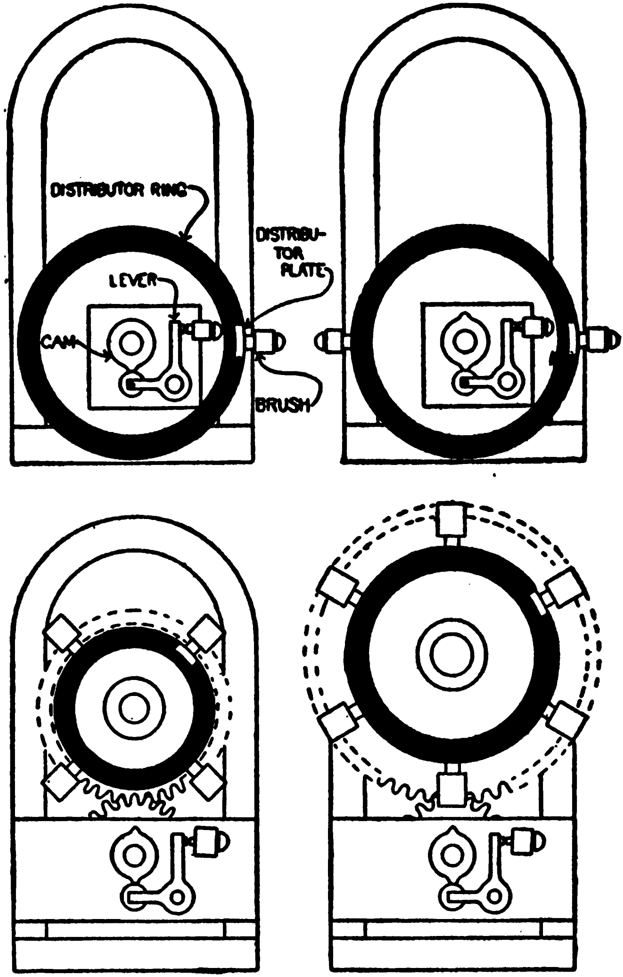


FIG. 42.—DISTRIBUTORS FOR ONE, TWO, FOUR, AND SIX CYLINDERS.

may touch the insulated block or move away from it. The lever is pivoted to the metal of the magneto, so that a current that flows to the lever may pass to the metal of the magneto; or, in other words, to **ground.** The inside end of the armature winding is **grounded** by being screwed to the armature core, so that a current may pass from the core to the winding; the outer end of the winding is attached to the insulated block of the circuit breaker.

When the lever touches the insulated block, a current produced in the armature winding has a complete circuit in which to flow, for it may pass to the insulated block, to the lever, to ground; or, in other words, to the metal of the magneto, and thence to the armature core and back to the winding. When the lever moves away from the block, this circuit is broken, and the current is forced to seek another path by which to return to the armature winding.

In ignition magnetos, the circuit breaker

holds the circuit closed during all of the time when the current is weak. When the armature reaches positions C or G, or some point just beyond them, the lever is separated from the insulated block, and the intense current that is then flowing is diverted in such a manner that it forms an ignition spark.

The principle of a circuit breaker is shown in Figure 43. The lever is shown as a straight bar, pivoted at one end, and with a platinum point at the other end that may touch a corresponding platinum point on the insulated block. These parts are supported on the end of the magneto in such a manner that when the armature revolves, a cam on its shaft touches the lever and makes it move away from the insulated block. The cam has two projections, so that it will cause the lever to move twice during each revolution of the armature.

It has been explained that a magneto can give a spark at any point from position C to position D, and from position G to posi-

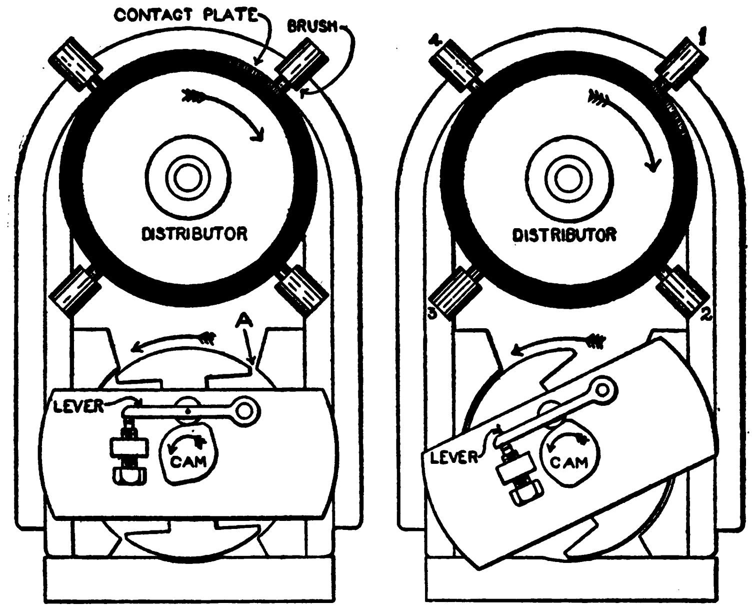


Fig. 43.—Principle of Spark Advance.

tion H. In order to produce a spark, the circuit breaker must break the circuit at some point in this range, and this is under the control of the driver. As indicated in Figure 43, the circuit breaker is so mounted that it may be turned on the end of the magneto, just as the cover of a pill box may be turned, but it may be turned only through a short distance; this permits the advance and retard of the spark. When the circuit breaker is turned as far as it will go in the opposite direction to the way that the armature is turning, as indicated in the first sketch (Fig. 43), the lever will be moved when the armature is passing position C or G, and the spark will be advanced. When the circuit breaker is moved as far as it will go in the same direction as the armature is turning, the lever will not be moved until the armature has reached position D or H, as indicated in the second sketch, and the spark will be retarded.

Figure 43 also shows a distributor, and it

will be seen that the advance and retard of the spark will not move the distributor brush out of contact with the proper block.

A magneto is set on the engine so that the circuit breaker lever is beginning to move in the fully retarded position when the piston is at top dead center. Peculiarities of engine construction may make a difference in the setting of the magneto, however, and the setting that will give the greatest power can usually be determined only by experiment.

A magneto is so arranged that the production of sparks may be stopped, and this is usually done by giving the armature current a path by which it may flow, regardless of whether the circuit breaker is open or closed. Having such a path, the movement of the circuit breaker does not affect the flow of current, and the production of sparks ceases.

The insulated block is connected to one side of a switch, the other side of which is grounded by being connected to the metal

of the engine. To produce ignition this switch must be open; to cut out ignition the switch is closed.

Ignition magnetos may be divided into two classes; those that produce their own sparking currents directly in the armature, and those whose currents have not sufficient pressure to form a spark, and that require to be intensified by means of a device called a **transformer coil.** The first is called the **true high tension** type, and the second is the **transformer** or **step-up type**; of the two, the true high tension magneto is in more general use.

CHAPTER VIII

TRUE HIGH TENSION MAGNETOS

THE distinguishing feature of the true high tension magneto is the armature winding, which is made up of a few layers of coarse wire, and on top of these a very great number of layers of fine wire. The circuit breaker is connected only to the coarse wire, which forms the **primary winding**; the fine wire forms the **secondary winding**, and it is in this that the sparking current is generated.

The relation of these parts is shown in Figure 44. One end of the primary winding is shown attached to the insulated block of the circuit breaker, while the other leads to the circuit breaker lever; when the circuit breaker makes contact, a current may flow in the primary winding. One end of the secondary is connected to one end of the pri-

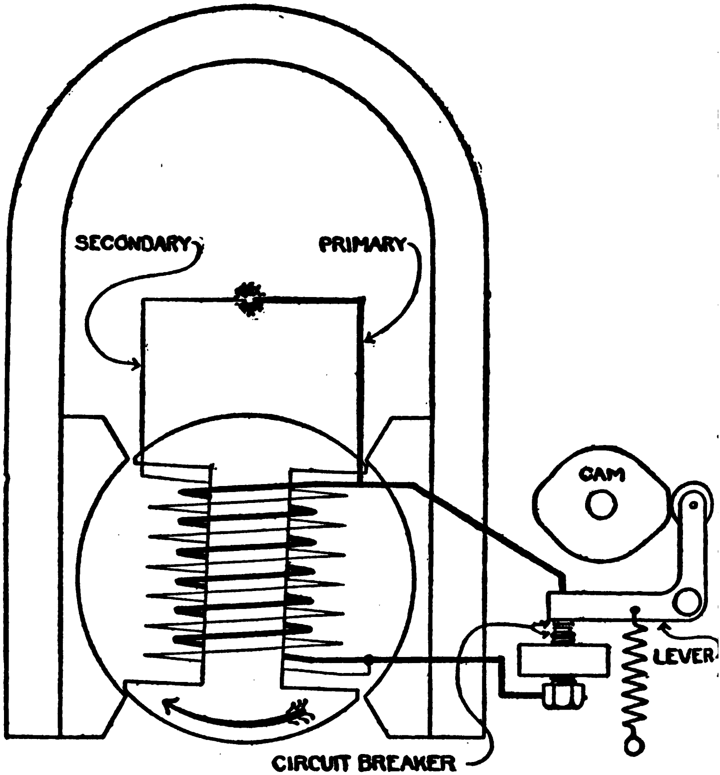


FIG. 44.—PRINCIPLE OF TRUE HIGH TENSION MAGNETO.

mary, so that the secondary is in effect a continuation of the primary; the other end of the secondary is shown as brought close to a wire attached to the remaining end of the primary. In order that current may flow in the secondary circuit it must thus jump across the gap between the ends of the wires, and pass through the primary to the point where the primary and the secondary are connected.

During those parts of the rotation of the armature when the circuit breaker is closed, a current will flow in the primary winding. The same changes in magnetism that produce this current will also tend to produce a current in the secondary winding. The secondary circuit is not complete, however, for it is broken by the gap between the ends of the wires, and without a complete circuit the current cannot flow. Thus there exists in the secondary winding a pressure that would make a current flow if it was great enough to force the electricity across the gap.

As the armature continues to revolve, and as it comes closer to position C or position G, the current in the primary becomes more intense; when the circuit breaker opens, this flow of intense current is diverted, for the only path then left for it is through the secondary winding. The extremely abrupt change in the strength of the magnetism of the armature core due to this diverting of the flow of primary current increases the pressure in the secondary winding to such an extent that it is easily able to jump across the gap. In jumping the gap it forms a spark of very great intensity.

In the construction of actual magnetos, the inner end of the primary winding is **grounded**; or, in other words, is secured to the metal of the armature core. The circuit breaker lever is also grounded, for it is mounted in such a way that it is in contact with the metal of the magneto. A current may thus flow through the metal of the magneto from the circuit breaker lever to the

armature winding. The outer end of the secondary winding is connected through the distributor to the spark plug, which is

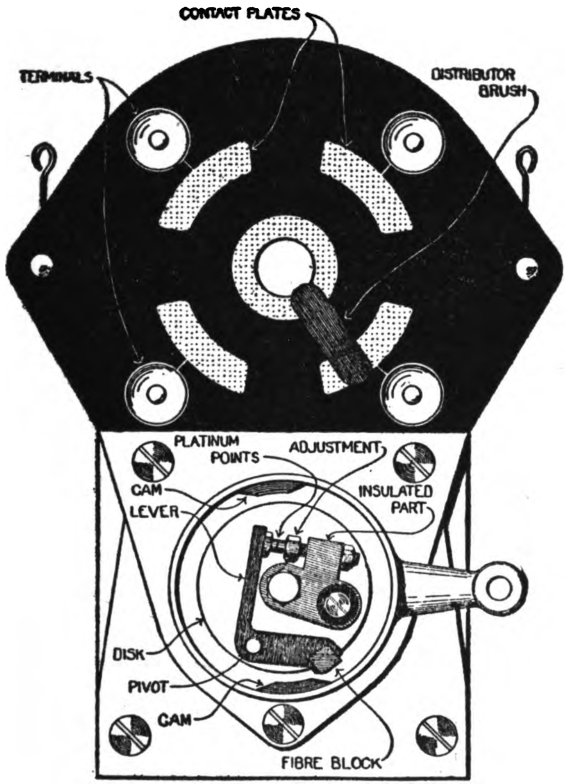


Fig. 45.—Bosch Magneto, Type D U, End View.

screwed into the cylinder and is thus in contact with the metal of the engine. A current that forms a spark at the plug passes to the metal of the engine, which provides a path by which it may flow to the metal of the magneto, to the grounded end of the primary winding, and thus may return to the secondary winding.

The principle thus outlined is employed in Bosch high tension magnetos, which are produced in a great variety of types, according to the requirements of different engines. Type D U is in very general use, and an end view of this type for a 4-cylinder engine is shown in Figure 45. A side view of this magneto, partly in section, is shown in Figure 46.

The Bosch circuit breaker is arranged on a disk that is attached to the armature shaft and revolves with it. The lever is L-shaped, with the pivot at the angle, and it is caused to move by two steel cam blocks that are attached to the inside of the housing that

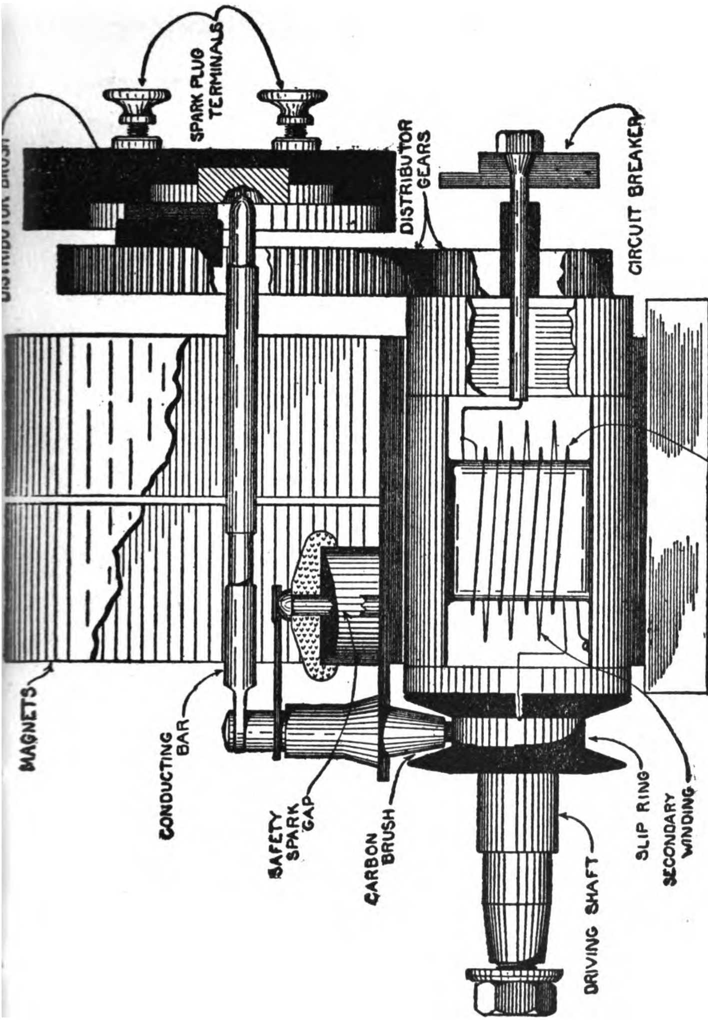


FIG. 46.—BOSCH MAGNETO, TYPE D U.

incloses the circuit breaker. These parts may be seen in Figures 45 and 47. By moving the housing, the lever may be made to strike the cam blocks earlier or later in the

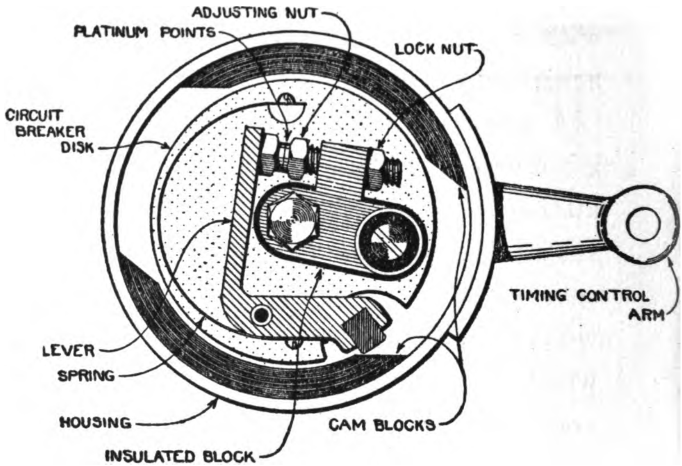


FIG. 47.—BOSCH CIRCUIT BREAKER.

rotation of the armature, which provides for the advance and retard of the spark.

The circuit breaker disk is secured to the armature shaft by a long bolt passing through its center, and, as may be seen from Figure 46, this bolt serves in addition to con-

duct the current from the primary winding to the insulated block of the circuit breaker. In order to remove the circuit breaker the bolt is unscrewed; the circuit breaker cannot be replaced incorrectly, for it is provided with a key that fits into a keyway in the armature shaft.

A deeply grooved hard rubber wheel with a metal ring in the bottom of the groove is attached to the other end of the armature shaft. This is the **slip ring**, by which the sparking current flows from the secondary winding. The outer end of the secondary winding is secured to this ring, and a carbon brush is so arranged that the ring passes under it in revolving. The sparking current passes from the armature to the slip ring and the carbon brush, and by a conducting bar to the distributor.

On the dust cover is a device called the **safety spark gap**, which is to the magneto what the safety valve is to a steam boiler. The safety spark gap consists of a pointed

brass rod set in the dust cover and therefore grounded, and a second brass rod set in the porcelain cover of the gap housing in such a manner that the two are separated by a fixed distance. The upper rod is connected to the brush that presses against the slip ring. Any sparking current produced in the armature may flow by jumping across the spark plug gap, or by jumping across the points of the safety spark gap. The distance between these points is such that it is easier for the current to jump across the spark plug gap, and the current therefore takes that path whenever it is able to do so. Should one of the spark plug cables break or fall off, or should the spark plug gap be too wide, the magneto current will then pass across the safety spark gap. Without the safety gap, the current would make a path for itself by breaking through the insulation of the armature winding and jumping to the core, which would ruin the armature.

A spark at the safety gap indicates a fault

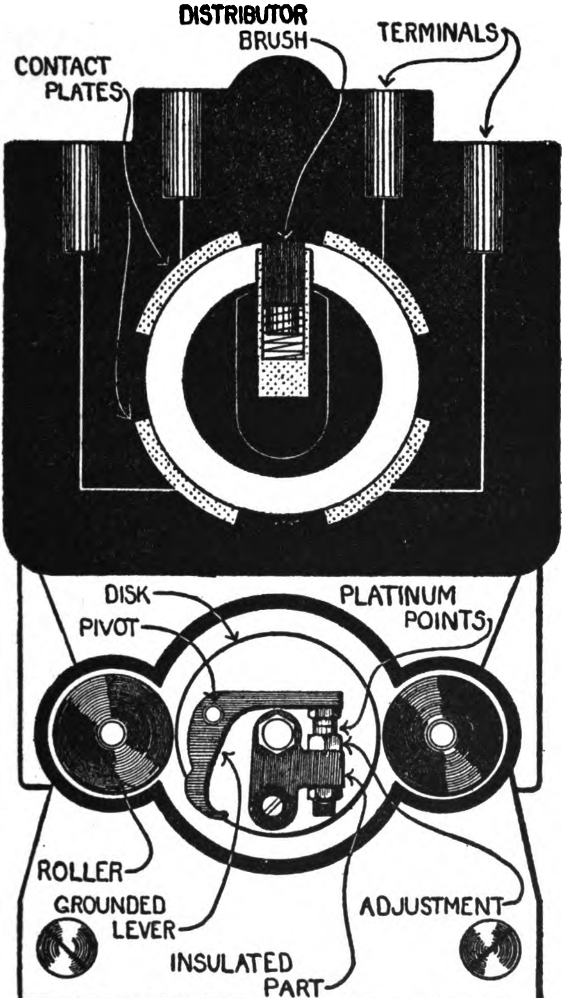


Fig. 48.—Bosch Magneto, Types D and D R, End View.

in the spark plug circuit, and the fault should be located and corrected without loss of time.

The circuit breaker housing or the housing cover carries a flat spring that presses against the head of the long bolt, and is thus in connection with the primary circuit. This spring is insulated from the magneto, but is attached to a binding nut, to which is connected a wire that leads to a switch; another wire leads from the switch to any metal part of the engine. By closing the switch, a circuit is provided between the insulated block of the circuit breaker and the metal of the engine, and as the current will then have a path to ground even when the circuit breaker is open, the instant result will be the stopping of the ignition spark. The switch must be open in order that the engine may run.

Bosch magnetos of the D and D R types are similar in arrangement, as shown in Figures 48 and 49. The distributor plate is fixed

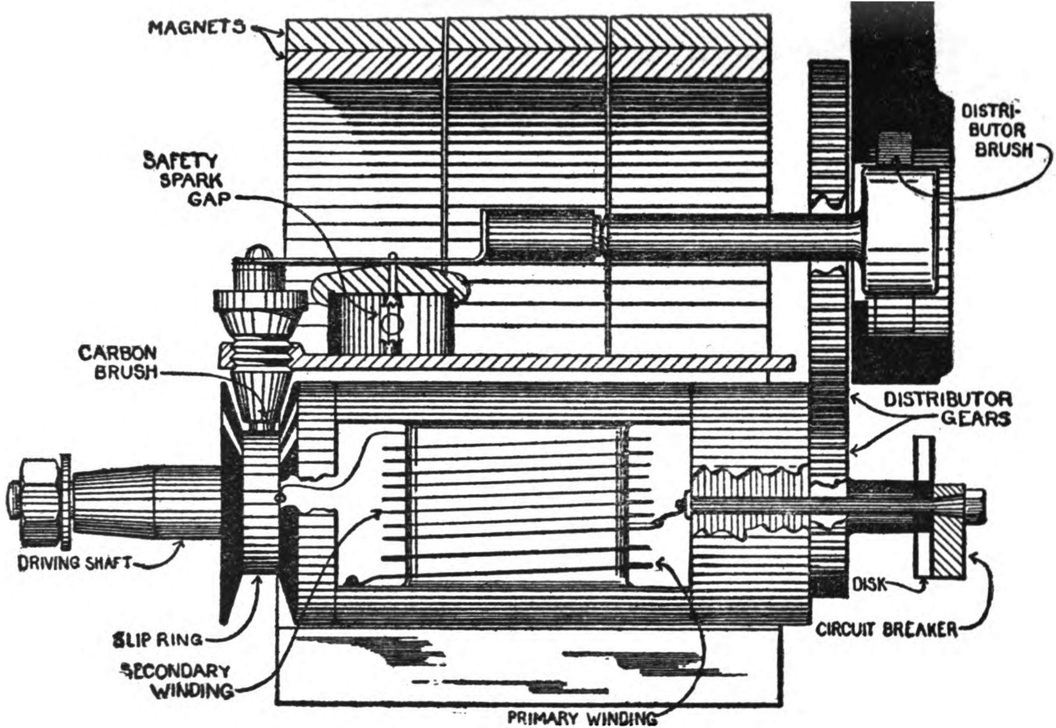


FIG. 49.—BOSCH MAGNETO, TYPES D AND D R.

on the magneto instead of being easily detachable, however, and by removing the three-armed clamp on its face the distributor cover may be removed, and the revolving brush and its holder pulled out. The circuit breaker lever is operated by two fiber rollers instead of by steel cam blocks, as used on the D U type. The D U also has two single magnets, while the D has three double magnets and the D R two double magnets.

The Bosch Z R type of magneto is entirely different in appearance from those already described, although the arrangement and action are unchanged. It has the advantage of being unaffected by water and dust. To provide for this, the magneto is entirely inclosed, and the terminals are of such a form that water cannot cause a short circuit. The appearance of the magneto is shown in Figure 50.

In some of the forms of the Z R the cables are attached as indicated in Figure 51. The cable is cut off square, and pushed to the bot-

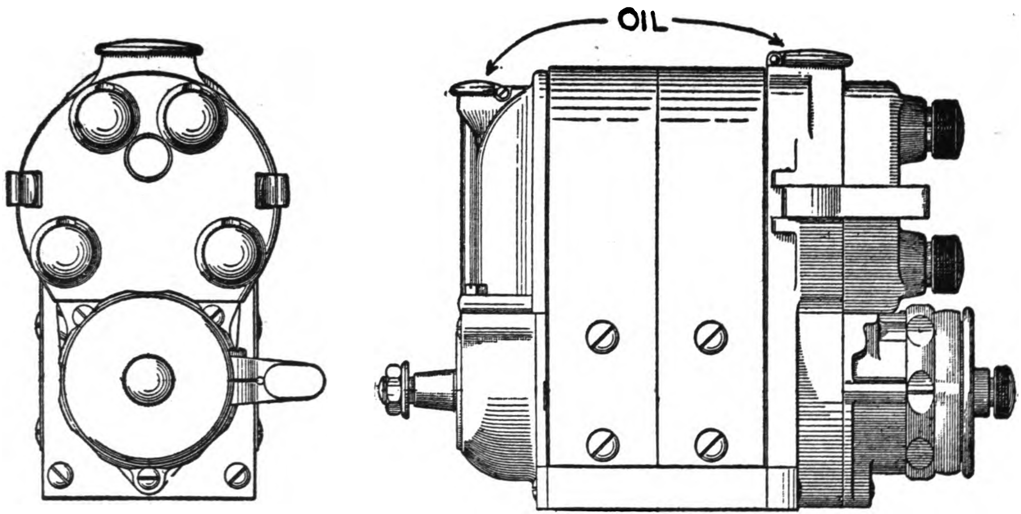


FIG. 50.—BOSCH MAGNETO, TYPE Z R.

tom of a hole in the distributor plate or the brush holder, in which it fits snugly. A pointed screw is then screwed through the side wall of the hole, piercing the cable and connecting the wire with a metal block that communicates with the circuit. This also has the effect of jamming the cable tightly in the hole. As the hole does not go through, water and dust cannot penetrate to the interior of the magneto.

FIG. 51.—CABLE CONNECTION OF BOSCH Z R MAGNETO.

Figure 52 shows the connections of a 4-cylinder magneto, and magnetos for any number of cylinders are connected in a similar manner. Each distributor terminal is connected to its proper spark plug, according to the firing order of the engine, and the only

other wire necessary is the switch connection.

A specific rule for the **timing**, or **setting**, of a magneto cannot be laid down, because

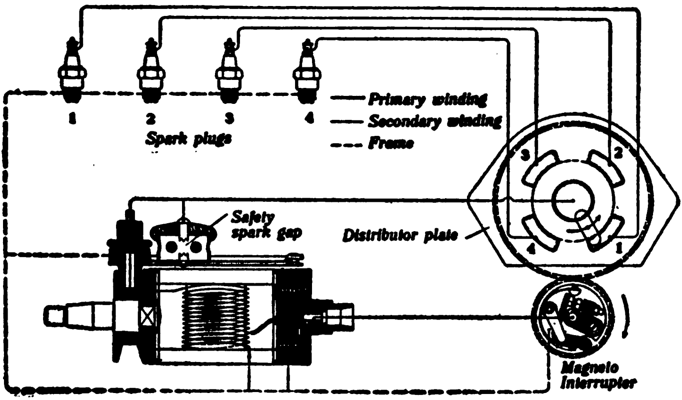


FIG. 52.—MAGNETO CONNECTIONS.

the variations in engine design and construction may result in corresponding variations in the ignition point. It may be said, however, that an engine will run if the magneto is so set that the fully retarded spark occurs when the piston is at top center of its stroke. The setting that will give the greatest power output can be determined only by inquiry

of the makers of the engine or by experiment.

The magneto manufacturers publish complete and detailed instruction books, which explain the method of attaching and setting of each type of magneto. These books may be obtained for the asking.

Another series of Bosch magnetos is known as the 2-spark type, and has for its object the production of two sparks each time that the circuit breaker opens. As has been explained, the time that must elapse between the passing of the spark and the complete combustion of the mixture causes a loss of efficiency, and the engine designer endeavors to make the combustion space of such a form that the flame will sweep through it in the shortest possible time. By the use of a 2-spark magneto, ignition may be started at two widely separated points in the combustion space instead of at but one, which greatly reduces the time necessary for the complete combustion of the charge.

The use of the 2-spark system is especially advantageous in engines with wide combustion spaces, such as exist in T-head designs, but it may be used with excellent results on any form of engine, provided the spark plugs

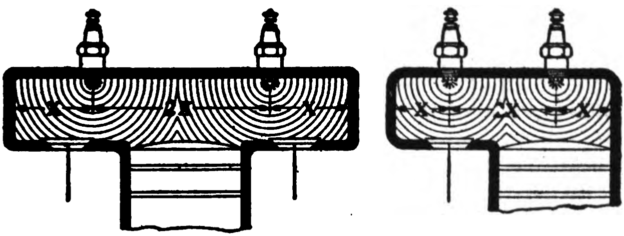


FIG. 53.—EFFECT OF TWO-SPARK IGNITION.

are separated by a distance of about half of the total width. (Fig. 53.)

A 2-spark magneto will increase the power output by 10 to 15 per cent., and will give greater flexibility of operation.

In single spark magnetos, one end of the secondary winding is grounded on the armature core through the primary winding, but on 2-spark magnetos this ground does not exist, for the secondary winding is grounded

through the second spark plug. In order to do this, the slip ring is made up of two segments, each extending about one-quarter the way around the slip ring wheel, instead of being a continuous band. These segments

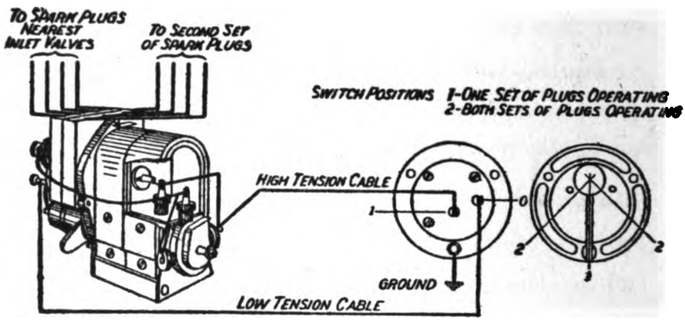


FIG. 54.—TWO-SPARK MAGNETO CONNECTIONS.

are connected to the ends of the secondary winding, and two slip ring brushes are set on opposite sides of the end plate.

The magneto is provided with a distributor plate of double thickness, which has terminals for the double set of spark plug cables leading to the engine. The distributor brush holder carries two brushes, one for each distributor, each brush being connected

to one of the slip ring brush holders. The sparking current passes from one of the slip ring brushes through its distributor to a spark plug, then by the metal of the engine to the second spark plug in the same cylinder, and returns to the armature by the second distributor and slip ring brush. (Fig. 54.)

The switch used with this magneto has three positions, the outside positions being marked 2, while the central position is marked 1. With the switch in either of the outside positions, both sparks will appear, while the inside position causes only one spark plug to operate. This is done by connecting one of the slip ring brushes to the switch, and making a further connection between the switch and one of the distributors. With the switch in position 2, the current flows from the armature to the distributor through the switch; when in position 1 the switch passes this current directly to ground, and consequently cuts the corresponding spark plug out of the circuit.

Position 1 is used in starting the engine and for slow running; position 2 is used when maximum power is required.

The arrangement of the circuit breaker is not changed, and the sparks are produced simultaneously at the instant when the platinum points separate.

CHAPTER IX

TRANSFORMER MAGNETOS

THE magneto used on a transformer system produces a current so low in voltage, or pressure, that it cannot break its way through air, no matter how small the air space may be. To use such a current for a jump spark system, it must be transformed to a current of high voltage, and this is done by means of an **induction coil.**

An induction coil consists of a core of soft iron, which is made of a number of pieces of iron wire rather than of a solid bar, because in that form it will gain and lose magnetism more rapidly. Around this core a few layers of coarse wire are wound, this forming the primary winding; on top of this is the secondary winding, which is made up of a great number of layers of fine wire. An induction coil is thus seen to be similar in construction

to the armature of a true high tension magneto.

When a current flows through the primary winding of a coil, the core becomes magnetized, and this increase in the strength of the magnetism results in the production of a high-pressure current in the secondary winding. When the current stops flowing in the primary winding the magnetism of the core dies away, and another rush of current is produced in the secondary winding. By making or breaking the primary circuit very abruptly the magnetism is caused to change its strength with great suddenness, and the currents that are produced in the secondary winding will have sufficient pressure to jump across the spark plug gap and to form a spark.

In transformer systems, the magneto current flows through the primary winding, and does not itself form the ignition spark; it produces a change of strength in the magnetism of the core, and the ignition spark is

formed by the current that then appears in the secondary winding.

The best known of the systems that operate under this principle are the Splitdorf and the Remy.

In the Splitdorf, the magneto current is not permitted to flow in the primary winding of the coil until it has reached its full intensity; the sudden rush of this intense current causes a sufficiently sudden production of magnetism around the core of the coil to generate a sparking current in the secondary winding.

Figure 55 shows the principle of the Splitdorf system. The armature core is of the usual shape, and is wound with a number of layers of coarse wire. One terminal of the winding leads to the insulated block of the circuit breaker, while the other terminal is connected with the circuit breaker lever. From these two points the connections are continued to the two ends of the primary winding of the coil, so that the magneto cur-

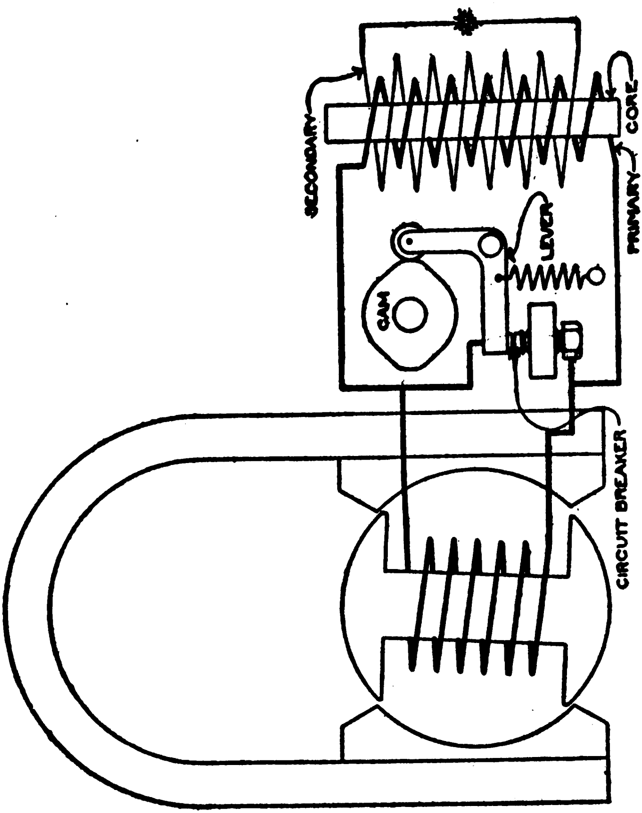


FIG. 55.—PRINCIPLE OF SPLITDORF MAGNETO.

rent has two paths by which it may flow, one being across the platinum points of the circuit breaker when they are touching, and the other being the primary winding of the coil.

It is much easier for the current to flow across the platinum points than through the primary winding, and consequently it will take that path whenever it can. The platinum points will be together while the armature is moving from position H toward position C (Fig. 40), and from position D toward position G, and the weak current then being produced will take the platinum point path. When the armature reaches position C and position G, the circuit breaker lever moves to separate the platinum points, and the current, no longer being able to take that path, must flow through the primary winding of the coil. The spark is thus produced at the instant when the platinum points separate.

In the actual magneto, the inner end of the armature winding is secured to the armature core, and is thus grounded; the circuit

breaker lever is pivoted to the metal of the magneto, and is also grounded. In addition, one end of the primary winding of the coil is connected to the metal of the engine, and it is thus seen that the metal of the engine and of the magneto will serve as a path by which the current may return to the armature winding from the circuit breaker or from the coil.

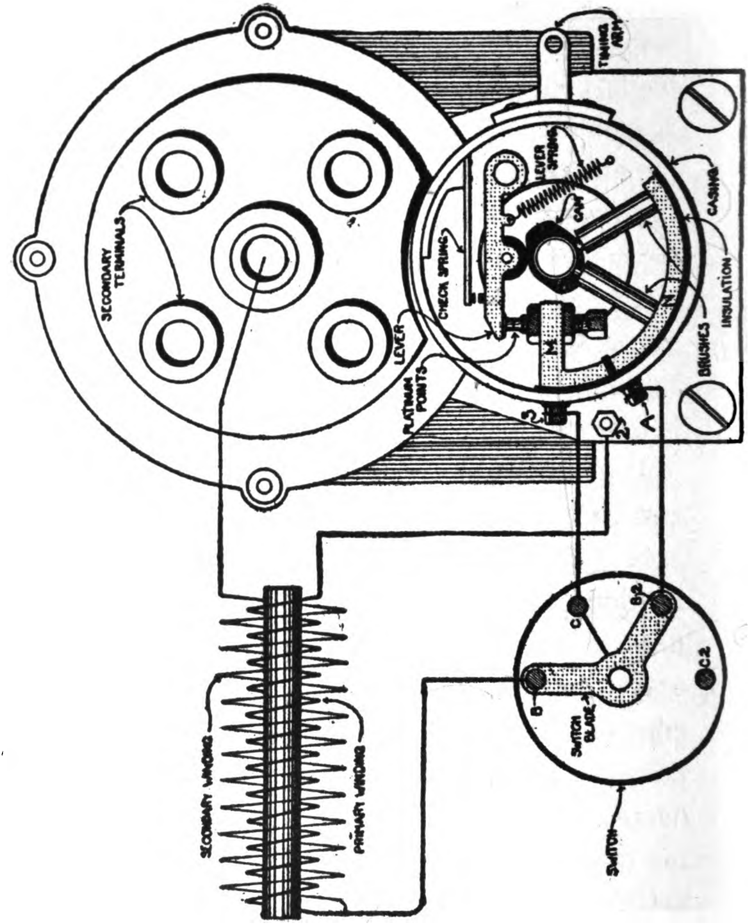
The outer end of the armature winding is attached to a rod that passes lengthwise through the armature shaft, but that is insulated from it. The rod projects beyond the end of the shaft, and a spring or brush that presses against the projecting end conducts the armature current to the insulated block of the circuit breaker.

One end of the secondary winding of the coil is connected to the primary winding, while the other end leads to the distributor. The secondary current thus passes to the plug, and returns to the secondary winding by the metal of the engine and the connection

between the engine and the primary winding of the coil.

Figure 56 is an end view of the Splitdorf magneto, and it shows the construction of the circuit breaker. The circuit breaker lever is pivoted at one end to the housing or casing, and it is operated by a cam attached to the armature shaft. A spring holds the lever against the cam, and a roller on the lever reduces the friction. A check spring keeps the lever from moving too far, and prevents the platinum points from opening too wide when the magneto is driven at high speed.

The current flows from the armature winding through the rod that is set in the shaft, and passes by the brushes to the insulated block N. Then it flows to switch contact B 2 by binding post A and the connecting wire. From this switch contact it may return to the armature by either of two paths; it may flow through the switch blade and the primary winding of the coil to mag-



SECONDARY TERMINALS
LEVER
PLATINUM POINTS
CHECK SPRING
LEVER SPRING
CAM
TIMING ARM
CASING
INSULATION
BRUSHES
M
N
A
2
3
C
B2
C2
B
SWITCH BLADE
SWITCH
SECONDARY WINDING
PRIMARY WINDING

neto binding post 2, and by ground to the armature, or may flow through the switch blade and switch contact C to binding post 3, insulated block M and to ground through the circuit breaker lever. This latter path is far easier for the current to flow in, and the current follows it as long as the platinum points are touching. When the points separate, the current has no choice but to flow through the coil, and it is then that the spark is produced.

The connections of the Remy magneto system are shown in Figure 57, and it will be seen that they differ from the Splitdorf connections in that the magneto current can flow through the primary winding of the coil only when the circuit breaker is closed. The core of the coil is thus magnetized by the flow of magneto current, and the sparking current is produced in the secondary winding of the coil by the dying away of the magnetism that occurs when the circuit breaker opens. The circuit breaker is arranged to

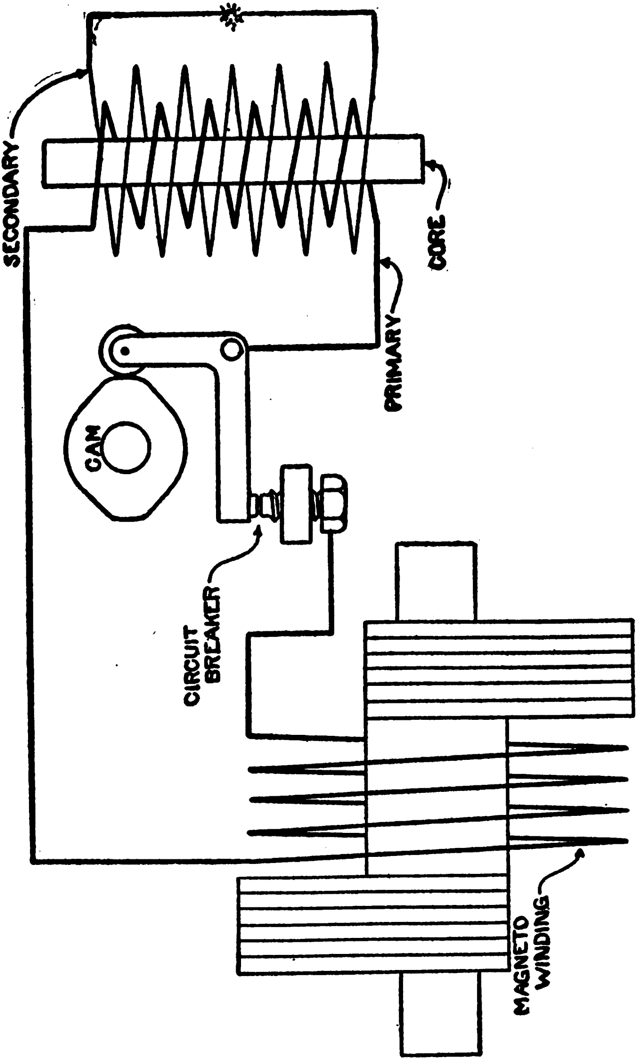


Fig. 57.—Principle of Remy Magneto.

open when the armature current is most intense, and when in consequence the core of the coil is strongly magnetized.

In the Remy magneto, the winding is not

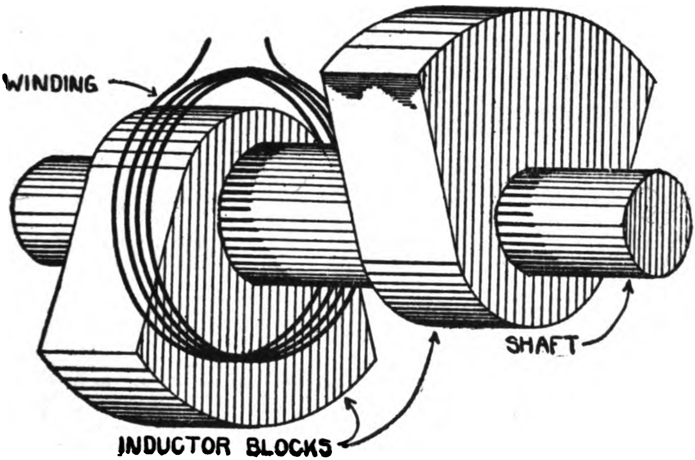


FIG. 58.—INDUCTOR OF REMY MAGNETO.

built into the armature, as is the case in the magnetos that have been described, but is separate from the armature core. This winding is stationary; the part that revolves is the armature core, which is called the **inductor**, and it consists of a shaft with two

blocks of iron projecting from it, as shown in Figure 58. When these blocks are up and down, the magnetism can flow between the ends of the magneto by way of the blocks. This corresponds to positions C and G. (Fig. 40.) When the shaft revolves to bring the blocks crossways between the ends of the magnets, the magnetism will flow into one block, through the part of the shaft that is between the blocks, and through the second block to the other end of the magnet. This corresponds to positions A and E. (Fig. 40.)

When the inductor is revolved, the part of the shaft lying between the blocks is alternately magnetized and demagnetized, and it is these changes in magnetism that produce currents in the winding. The coil of wire that forms the winding surrounds the part of the shaft that lies between the blocks, but does not touch it and does not revolve with it. One end of this coil leads to the insulated block of the circuit breaker, and the other is grounded.

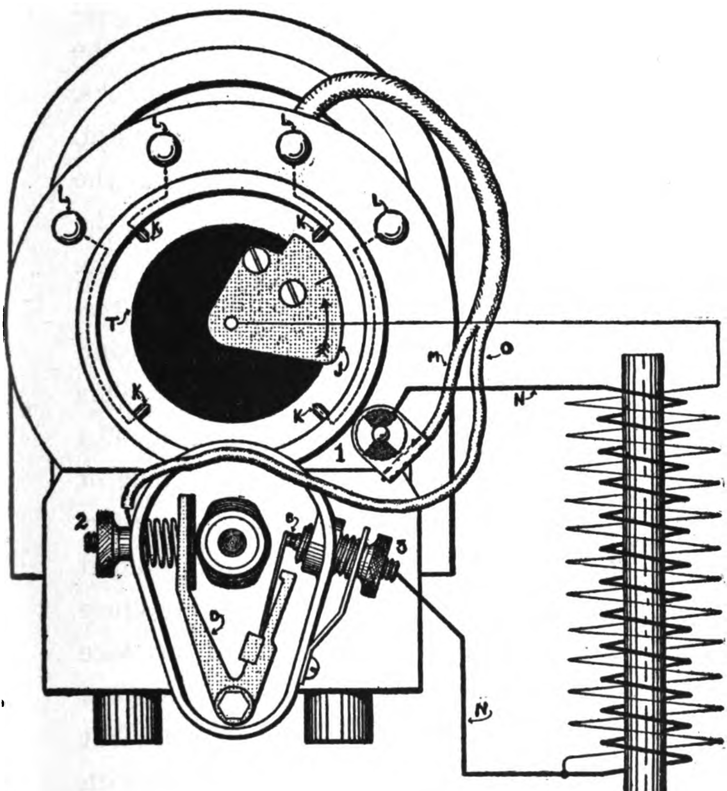


FIG. 59.—REMY MAGNETO IGNITION SYSTEM.

One type of Remy magneto is shown in Figure 59, and the sketch also indicates the connections. One end, M, of the magneto winding is connected to one end of the primary winding of the coil at binding post 1. The other end, O, is grounded at binding post 2. The remaining terminal of the primary winding of the coil leads to magneto binding post 3, which is located on the insulated block of the circuit breaker. When the circuit breaker is closed, the current can flow across the platinum points B, to the lever D, to ground, to binding post 2, and so to the magneto winding.

Figure 60 shows another type of Remy magneto, with a different construction of the circuit breaker.

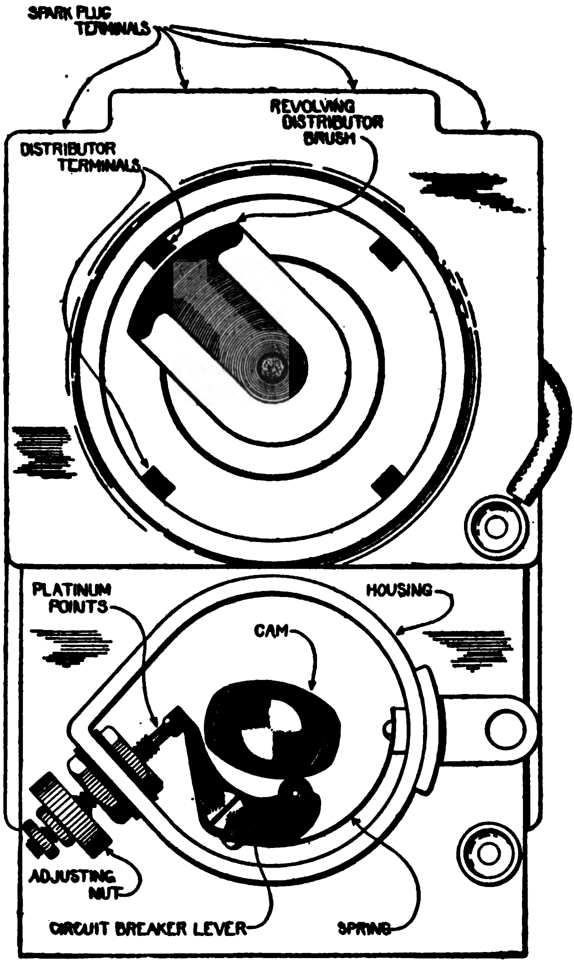


FIG. 60.—REMY MAGNETO, TYPE B D.

CHAPTER X

BATTERY IGNITION SYSTEMS

A MAGNETO can produce a current only when the armature is revolving, and in order to start on the magneto the engine must be cranked quickly enough to revolve the armature at a sufficient speed to produce a sparking current. With small engines and good mixtures there is no difficulty in doing this, but it may not be easy with large engines and imperfect mixtures. It is therefore quite usual for an engine to be fitted with an ignition system that will produce sparks regardless of whether the engine is running or at rest, in addition to the magneto. The current for such a system is obtained from a **battery,** which is made up either of **dry cells** or **storage cells,** the latter also being known as **accumulators.**

It has been seen that a magneto produces a current by the rotation of the armature,

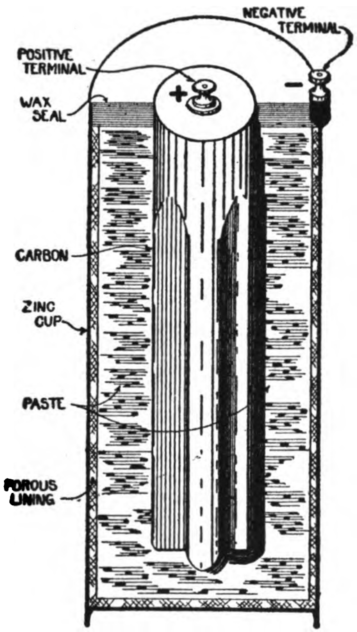


FIG. 61.—SECTION OF DRY CELL

for which power is required; the current is thus produced mechanically. A dry cell and a storage cell produce currents by the chemical action of some of the parts on the rest.

A dry cell consists of a zinc cup, a stick of

carbon, and a paste containing a chemical that under certain conditions will eat the zinc just as acid would eat it. The space between the zinc cup and the stick of carbon is packed with the paste, but the carbon and the paste are prevented from touching the zinc by a lining of blotting paper. (Fig. 61.)

A screw or nut attached to the stick of carbon, and another attached to the zinc cup, form the terminals; when they are connected to the circuit a current will flow from the carbon to the circuit, returning to the cell by the zinc. The moisture absorbed by the blotting paper and in the paste will form the conductor by which the current will flow from the zinc to the carbon, and complete its circuit.

No matter what the size of a dry cell may be, its current will have a working pressure of a little over one volt; a large cell, however, will give a greater quantity of current than a small one. As an ignition system will usually require a pressure of six volts to

operate it, something must be done to bring the pressure up to this point.

A crowd of people might be so dense that a man could not press his way through, but if four or five men line up behind him, the pressure that they can exert in working to-

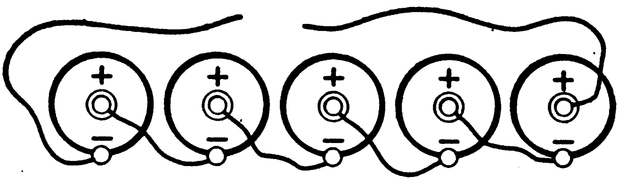


FIG. 62.—CELLS CONNECTED IN SERIES.

gether will gain them passage. Similarly, dry cells can be made to work together, and to give any pressure that may be required. To do this, the carbon terminal of one cell is connected to the zinc terminal of the next cell, as shown in Figure 62. The current from one cell must pass through the other cells in flowing over the circuit, and the voltage will be increased as many times as there are cells. If each cell gives one volt, for example, five cells connected in this manner

will give five volts. This is called connecting **in series.**

While a dry cell may be capable of giving a considerable quantity of current, this cannot be taken from it all at once. For instance, if a crowd of people try to rush through a doorway, they will become jammed in it; they will be able to get through only by passing one at a time. A dry cell will act in a similar way, for while it can give a small current for a considerable time, it will become choked, so to speak, if a heavy current is taken from it. The flow of current will then cease entirely. The cell must be permitted to stand idle, and be given a chance to **recuperate,** before it will again be able to deliver a current.

It is quite usual for an automobile to be supplied with five or six dry cells connected in series, but matters will be greatly improved if ten dry cells are used, connected as shown in Figure 63. The cells are divided into two groups of five cells each, the cells

of each group being connected in series; the free carbon terminals of each group are then connected together, and so are the free zinc terminals. Carbon and zinc are then con-

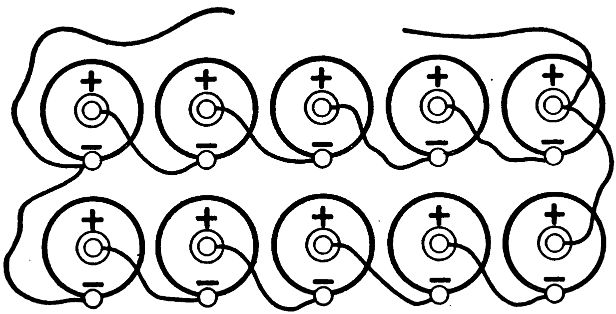


FIG. 63.—CELLS CONNECTED IN SERIES-MULTIPLE.

nected to the circuit in the usual manner. This is called connecting in **series-multiple, or series-parallel.**

Ten cells connected in series-multiple will give a current at the same pressure as five cells connected in series, but will give a greater quantity of current; or what is more important, will give an equal quantity of current for a much longer time. Ten cells

connected in series-multiple will last longer than ten cells used five at a time.

A storage cell operates on a different principle, for when in a normal condition it is not capable of giving a current. If a current is passed through it, however, the parts of the cell undergo chemical changes, and become converted in composition. When given an opportunity they will then change back to their original condition, and in so doing will produce a current nearly equal to the current used in converting them. Electricity is not stored in a storage cell as water is stored in a tank; a storage cell might be compared with a spring that requires power to stretch it, and that delivers nearly equal power in snapping back to its normal form.

A storage cell gives a current at a pressure of about two volts, and the quantity of current that it can deliver depends on its size; it is spoken of as having so-and-so-many **ampere-hours capacity**. An 80-ampere-hour cell is one that will give a current of one am-

pere for eighty hours, or a current of two amperes for forty hours, or a current of four amperes for twenty hours. A storage cell should be permitted to deliver only a small current; if it is short-circuited, the great rush of current will tend to heat it, and to injure or destroy it.

When a storage battery is used, it is most advisable to secure an instruction book from the maker. This will give explicit directions for the use and care of the battery, and these directions should be scrupulously followed.

All battery ignition systems operate by means of an induction coil, such as is described in the chapter on transformer magnetos. The battery current flows through the primary winding of the coil and magnetizes the core; at the instant when the spark is required the battery circuit is broken, and the dying away of the magnetism produces a sparking current in the secondary winding.

In addition to the battery and coil, the system must include a **timer**, which is a revolv-

ing switch that controls the flow of battery current through the coil.

In the Bosch battery system, the timer is a pivoted lever that makes and breaks the

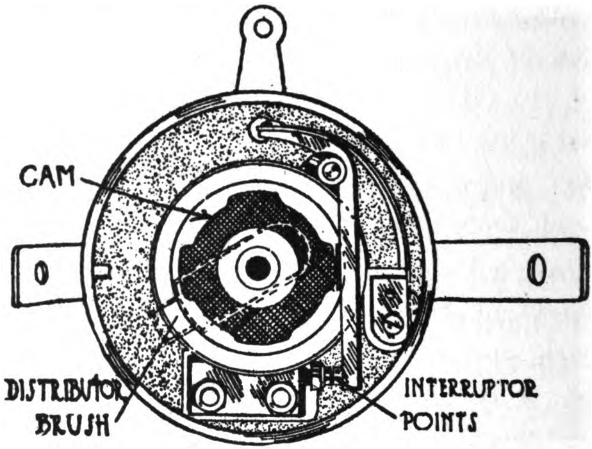


FIG. 64.—ACTION OF BOSCH TIMER-DISTRIBUTOR.

circuit; the cam that operates it has as many projections as the engine has cylinders. (Fig. 64.) Just before a piston reaches the firing point, the cam permits the platinum points to come together, and the battery current thereupon flows through the primary winding of the coil. At the instant when the

spark is required, the cam moves the lever, thus separating the platinum points and breaking the circuit; a sparking current is then induced in the secondary winding of the coil, and it is delivered to the proper cylinder by the distribution that is built into the timer. The appearance of the Bosch timer-distributor is shown in Figure 65. This system produces a single spark, and a very intense one, at the instant when the timer breaks the circuit.

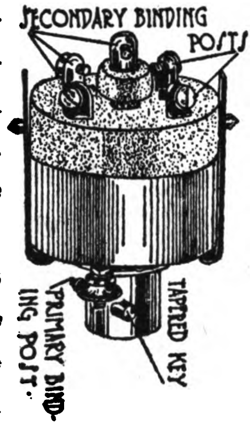


FIG. 65.—BOSCH TIMER-DISTRIBUTOR.

When starting a cold engine, it is frequently difficult to draw a proper mixture into the cylinder, and this is particularly true with the low grades of gasoline on the market. Under such conditions, ignition will be more sure if a shower of sparks is sent through the mixture instead of a single

spark; the first sparks heat up the surrounding particles of mixture, which are then easily ignited by the following sparks. To produce this shower of sparks the coil is provided with a device that makes and breaks

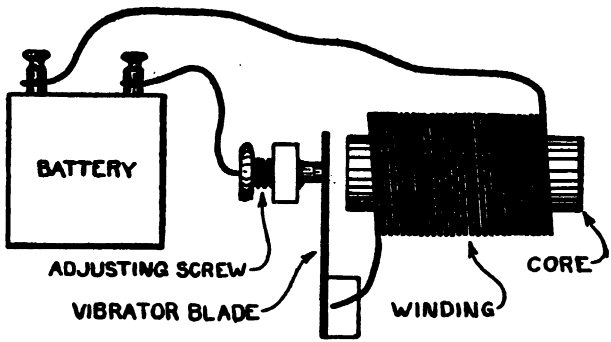


FIG. 66.—PRINCIPLE OF VIBRATOR.

the battery circuit a great number of times during the period when the timer contacts are open.

This device is called the **vibrator**, and Figure 66 shows the principle of its operation. It consists of a strip of iron supported at one end, and with the other end opposite one end of the core of the coil. When the core is mag-

netized it will attract to it the free end of the iron strip, or **vibrator blade,** as it is called. On the dying away of the magnetism, the free end of the blade will spring back to its original position.

The connections are so made that the battery current flows to a platinum tipped screw, thence to the blade when it is touching the screw, and from the blade to the winding of the coil. When the core becomes magnetized, it draws the blade away from the screw, and this movement breaks the circuit; the consequent dying out of the magnetism of the core induces a sparking current in the secondary winding, and at the same time permits the blade to spring back into contact with the screw. The vibrator moves hundreds of times a second, and a corresponding number of sparks is produced.

In the Bosch coil, the parts of which are shown in Figure 67, the vibrator is set in action by pressing the button in the end plate of the coil housing; when the button is

pressed in and turned to the right, the vibrator is maintained in action. The vibrator should be used only in starting the engine; when the engine is running the button should be released.

In many battery systems the vibrator is

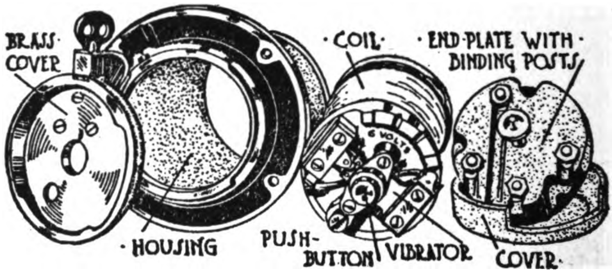


FIG. 67.—BOSCH COIL.

permanently in circuit, and a shower of sparks is produced whenever the timer makes contact. The first of these sparks ignites the mixture; by the time that the rest of them pass the mixture is ignited, and they are therefore wasted. Furthermore, the constant movement of the vibrator blade causes the rapid wear of the platinum points; for

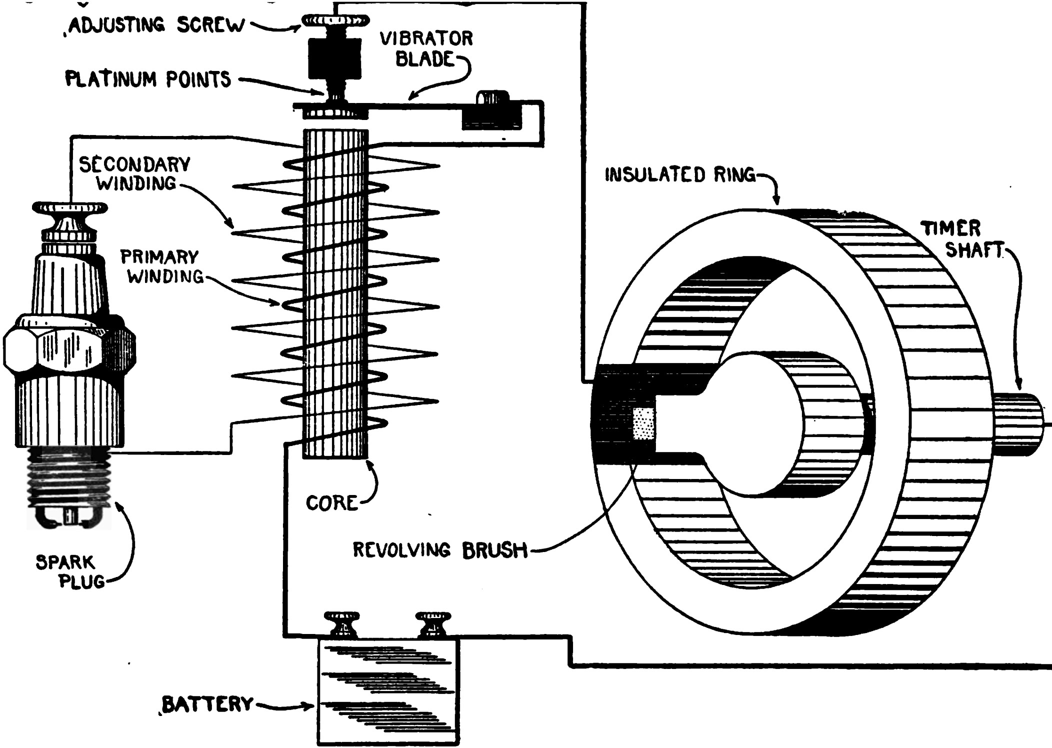


FIG. 68.—PRINCIPLE OF BATTERY IGNITION SYSTEM.

these reasons the use of a vibrator coil is dying out.

The principle of the vibrator coil ignition system is shown in Figure 68. The timer consists of a ring of insulating material, with metal plates set in it, one for each cylinder; the diagram shows a single cylinder timer. The connections between the battery, coil, vibrator and timer contact plate are indicated; the remaining terminal of the battery is grounded, and as the revolving brush is attached to a shaft driven by the engine, it is grounded also. The circuit is consequently closed when the brush touches the contact plate.

In vibrator coil systems, it is frequently the case that each cylinder has its own coil. Figure 69 shows the connections for a two-cylinder horizontal engine; the coil box contains two complete and independent coils, and the timer has two contact plates, one for each coil. At the instant when one of the pistons reaches the firing position, the timer

will make contact with one of the coils, and the sparking current that is then produced will be led to the proper spark plug.

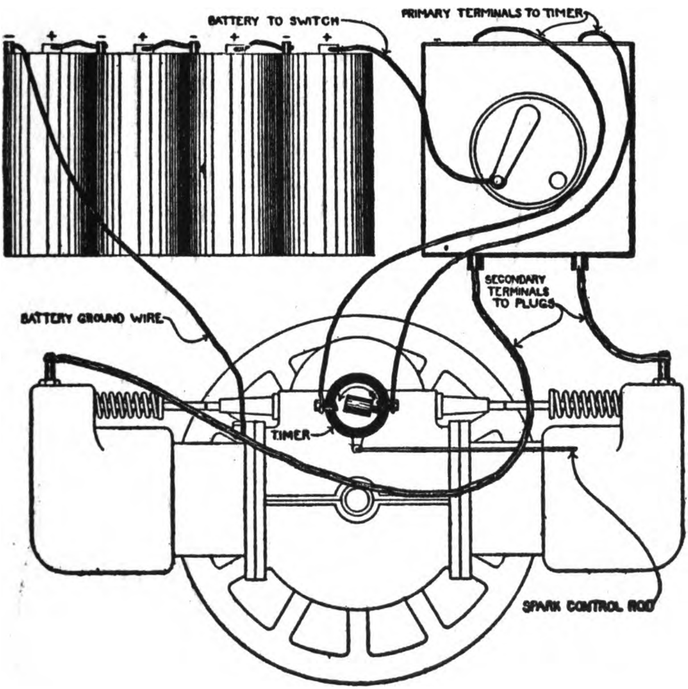


Fig. 69.—Connections of Two-cylinder Battery System.

Figure 70 shows the connections of a four-cylinder system. The coil box contains four

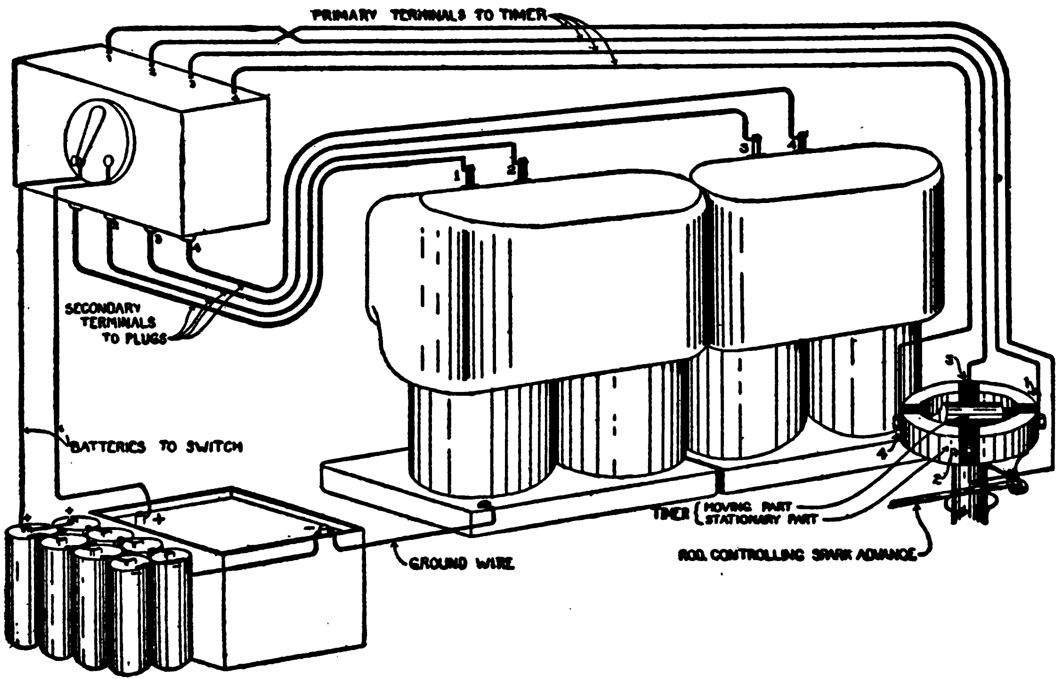


Fig. 70.—Connections of Four-cylinder Battery System.

coils, and the timer has four contacts. It will be noticed that the secondary terminals of the coils are connected to the spark plugs in a regular manner; that is, the left hand coil is connected to plug No. 1, the second coil from the left is connected to plug No. 2, and so on. The firing order of the engine is either 1, 2, 4, 3, or 1, 3, 4, 2, and the primary windings of the coils must be connected to the timer in such a manner that the sparks will be produced in corresponding order.

The timer is shown in contact with the connection to coil No. 1. Turning in the direction of the arrow, it will next make contact with the connection of coil No. 3; coil No. 4 will then be brought into circuit and then coil No. 2. This is done by the manner in which the primary windings of the coils are connected to the timer.

Figure 71 shows a cross-section of a coil, with its connections to the battery, the timer and the spark plug.

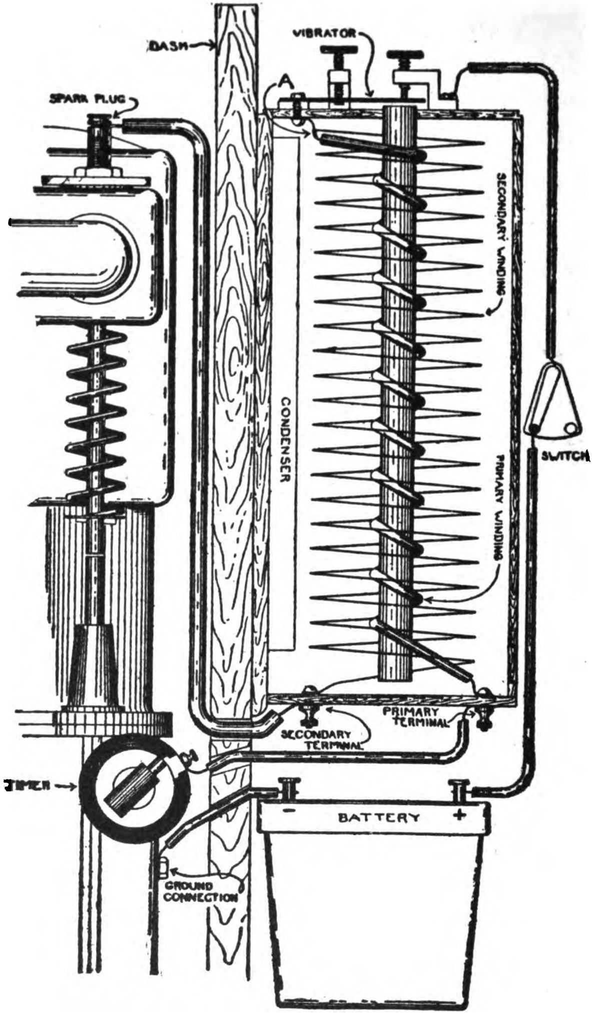


Fig. 71.—Vibrator Coil and Engine.

In such a system as this, each coil has its own vibrator, and the adjustment of these vibrators so that the coils will all act alike is not an easy matter. Figure 72 illustrates what is known as the **master vibrator** system, in which only one vibrator is used for the entire set of coils. By studying the diagram it will be seen that the vibrator is connected to one terminal of the primary winding of each coil; the other terminals of the primary windings lead to the timer contacts according to the firing order of the engine. By this arrangement the coils act in a uniform manner.

Vibrator coils are frequently used with a combined timer and distributor, similar in arrangement to the Bosch timer-distributor that has been described. The connections of such a system are shown in Figure 73. The timer has four contacts, but these are connected to the primary winding of the single coil; the battery current will thus flow through this winding whenever the timer

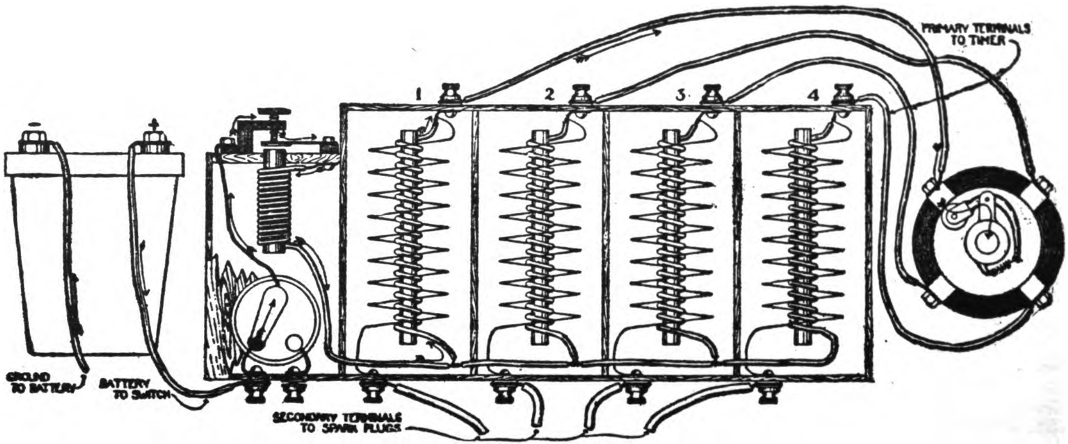


FIG. 72.—MASTER VIBRATOR BATTERY SYSTEM.

brush touches one of the contacts. The secondary terminal of the coil leads to the revolving distributor brush, and the sparking current is thus passed to the proper spark plug. The illustration shows the parts of the timer-distributor as being separated, but in the actual apparatus they are close together, and inclosed in a dust-proof housing.

In the Delco ignition system a vibrator coil is used, but a device is provided that permits the vibrator to make only one movement. By this means the quantity of battery current used is reduced.

The Atwater Kent system secures a reduction in battery consumption by an extremely brief closing of the battery circuit. This is done by mechanical means, and the movement of the contact blade is so rapid that it cannot be observed. The period during which the primary circuit is closed is so brief that the core of the coil cannot become thoroughly magnetized; the spark is due to the

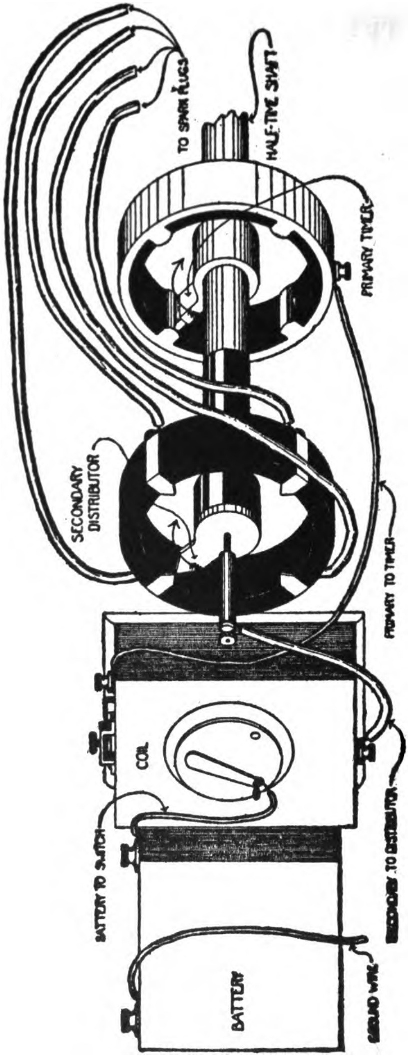


FIG. 73.—TIMER-DISTRIBUTOR WITH VIBRATOR COIL.

extreme abruptness with which the circuit is broken, and the correspondingly abrupt dying away of such magnetism as has been produced.

CHAPTER XI

COMBINED MAGNETO AND BATTERY SYSTEMS

WHILE a magneto is considered to be the best generator of an ignition spark, it is capable of giving a sparking current only when the armature is revolving. It is therefore customary to add to the engine equipment a battery system that will produce a sparking current at slow cranking speed, or when the engine is at rest.

Some automobile makers believe that if a second ignition system is provided, it should be so complete that it can be used in case the magneto should cease to give service, and they arrange the engine with a drive for a timer or a timer-distributor in addition to the magneto drive, and place two spark plugs in each cylinder; one for the magneto and one for the battery system.

The Bosch battery system is used for the battery side of such an arrangement, and the manner in which the connections are made is shown in Figure 74. The switch, which is

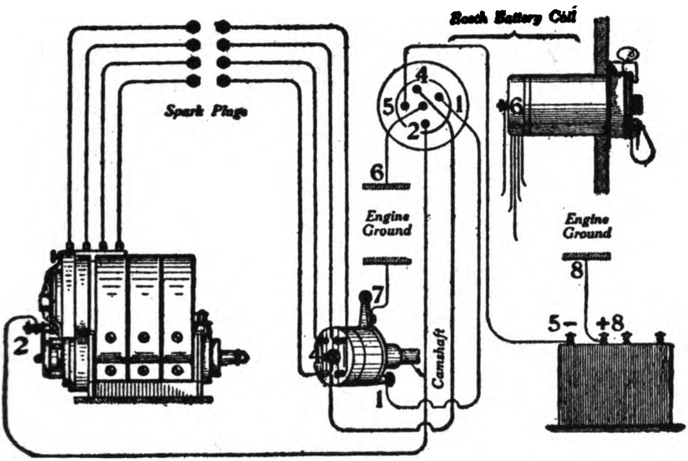


Fig. 74.—Connections of Bosch "2-independent" System.

combined with the coil, permits the engine to be run on the magneto alone, on the battery system alone, or on both battery and magneto, in which case both sets of spark plugs will operate.

In order to simplify the construction of

the engine, the parts of the battery system are frequently combined with the magneto to

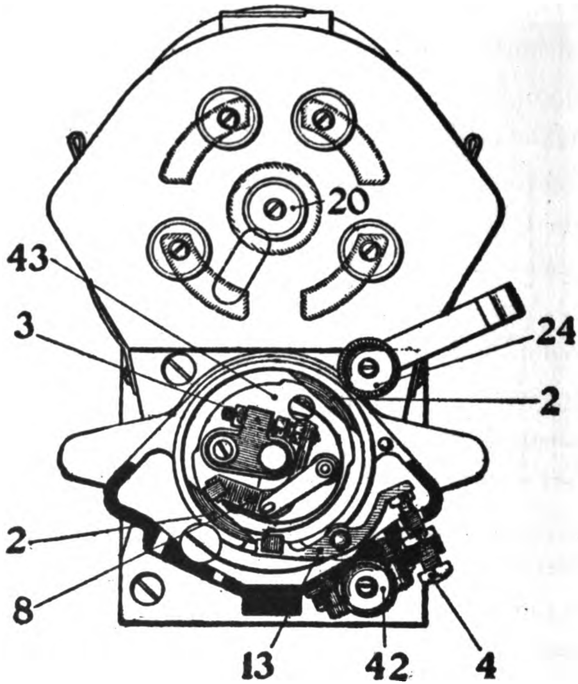


FIG. 75.—BOSCH DUAL MAGNETO.

form a **dual system.** The Bosch dual ignition system consists of a standard direct high tension magneto, to which are added parts

that are practically identical with the parts of the Bosch battery system.

Figure 75 shows an end view of a Bosch dual magneto. The magneto circuit breaker will be seen to be identical with the circuit breaker of the standard magneto, except that a steel cam with two projections is attached to the disk that carries the circuit breaker parts. The cam bears the number 43. A lever, 13, is pivoted on the magneto in such a position that its end is struck by the cam in revolving. The lever is thus caused to move on its pivot, and the platinum point that it carries is separated from the platinum tip of screw 4.

Screw 4 is insulated, and is connected to the battery system by binding post 42. The lever is grounded, and in consequence the battery circuit is closed through the primary winding of the coil when the lever touches the screw.

In the independent Bosch magneto the sparking current passes from the slip ring

directly to the distributor by an internal connection. In the dual magneto the distributor is used for the sparking current of the coil as well as for the sparking current generated

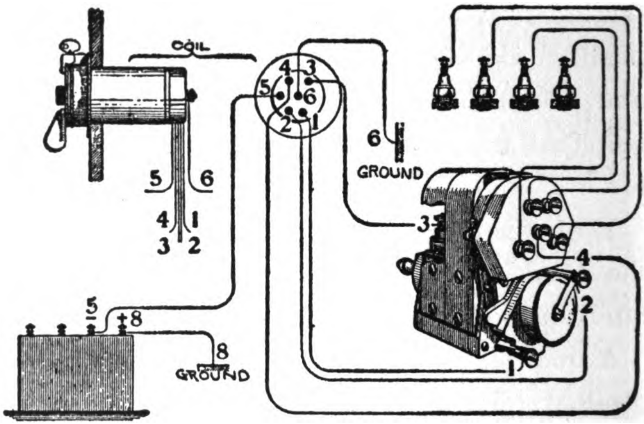


FIG. 76.—CONNECTIONS OF BOSCH DUAL SYSTEM.

by the magneto, and as these two currents cannot be flowing to the distributor at the same time, this internal connection is done away with. As shown in the wiring diagram of the system, Figure 76, the magneto slip ring, 3, is connected to switch terminal 3, and switch terminal 4 is connected to a bind-

ing post in the center of the distributor plate. When the engine is running on the magneto, the magneto current flows from the slip ring to the switch, and from there to the distributor. When the switch is in the battery position the magneto is cut out of circuit, and it is then the sparking current from the coil that flows over wire 4 to the distributor.

With the exception of the distributor and the spark plugs, the two systems are absolutely independent of each other.

A dual magneto can be converted to independent form by connecting slip ring terminal 3 to distributor terminal 4, using a heavily insulated wire. This will permit the engine to be run on the magneto, even with the coil removed from the car.

With the engine at rest and the switch in the battery position, the pressing of the button in the center of the switch plate will produce a vibrator spark that will be passed by the distributor to the proper cylinder; if the

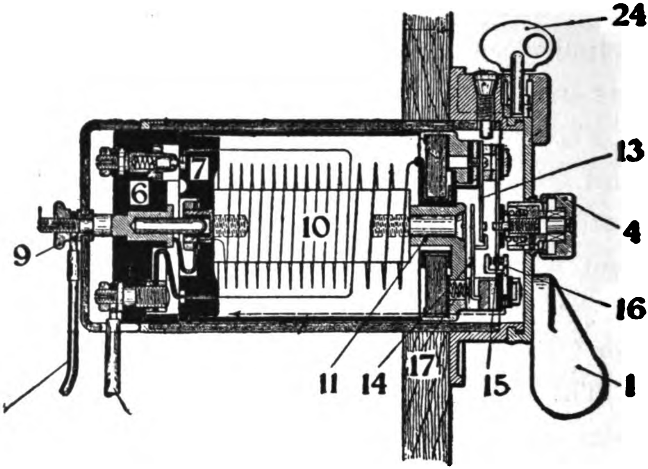


Fig. 77.—Bosch Dual Coil.

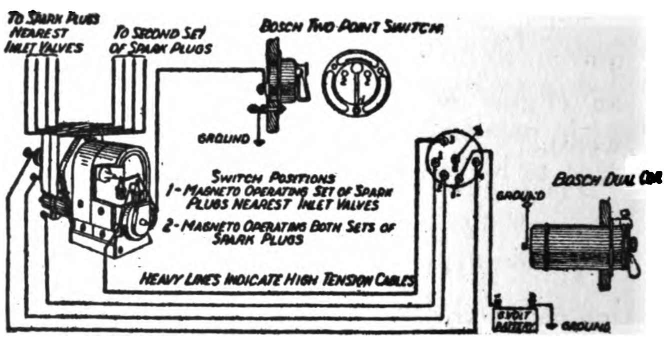


Fig. 78.—Connections of Bosch Two-spark Dual System.

cylinder contains gas, ignition will occur and the engine will start.

Figure 77 shows a cross section of the coil and the arrangement of the vibrator. When button 4 is pressed, its end comes into contact with spring 13, and closes the battery circuit through the primary winding; vibrator blade 14 will then operate.

The engine may be run on the battery system continuously, but the press button should be turned to the word " run "; a single contact spark will then be produced. The button should be turned to the word " start " only when a vibrator spark is required, as will be necessary when starting an engine on a poor mixture or in cold weather.

The connections of the Bosch 2-spark dual magneto are shown in Figure 78.

The Z R types of Bosch single and 2-spark magnetos are connected in a similar manner, except that switch terminal 4 leads to the shaft end of the magneto, from which point

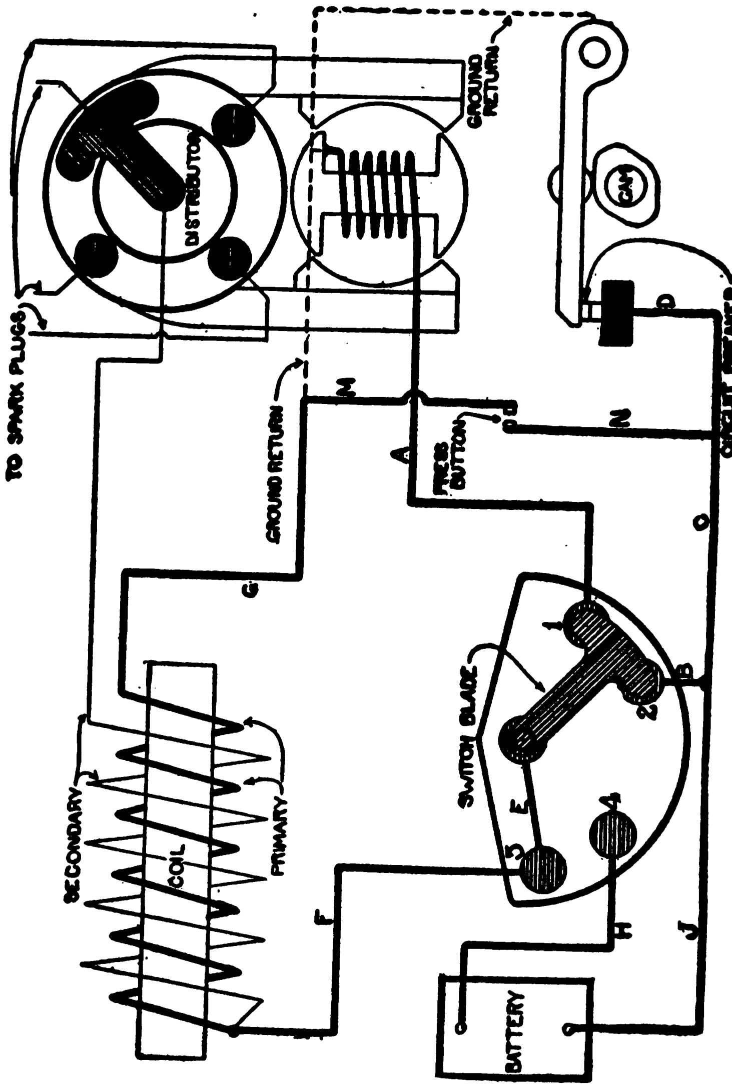


FIG. 79.—PRINCIPLE OF SPLITDORF DUAL SYSTEM.

an internal connection leads the sparking current to the distributor.

In the Splitdorf and Remy dual systems the magneto current and the battery current are transformed in the same coil and timed by the same timer.

The connections of the Splitdorf magneto are shown in Figure 79. With the switch blade in the position shown, the magneto will operate in the usual manner. When the switch blade is turned to connect switch terminals 3 and 4, the magneto will be cut out of circuit, and the battery will be thrown into circuit with the coil and the circuit breaker. When the engine stops with the magneto circuit breaker open, the pressing of the press button will close the circuit, and on releasing it a spark will be produced.

Figure 80 shows the connections of the Remy dual system, the action of which is similar to the action of the Splitdorf dual system.

In the Bosch duplex system a different

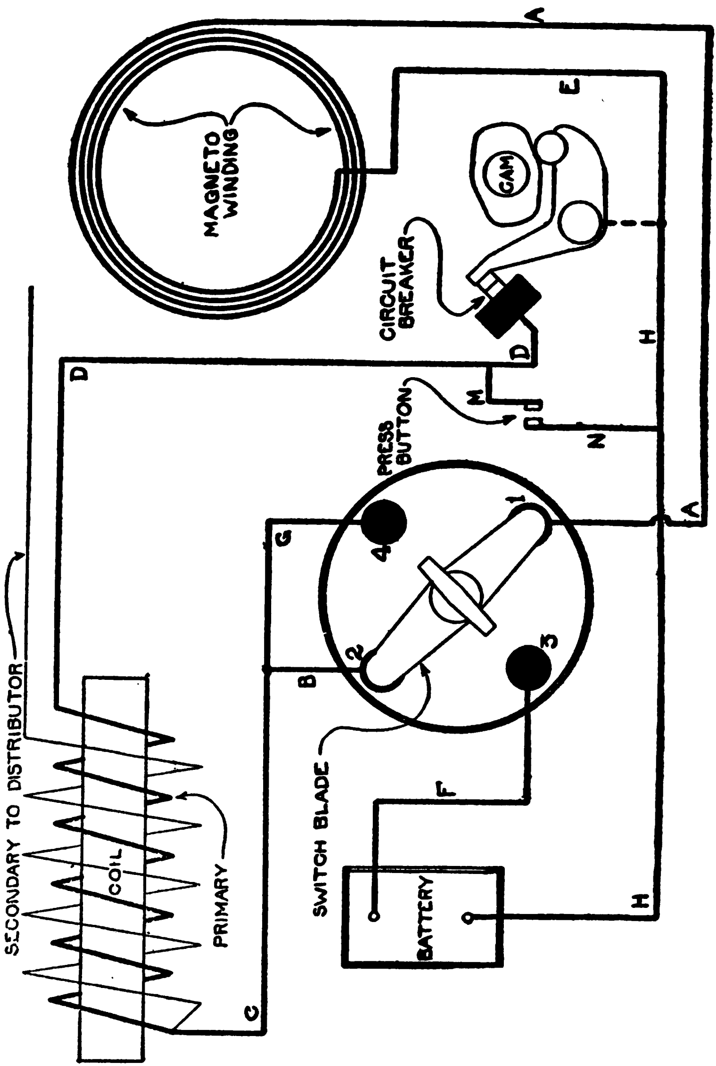


FIG. 80.—PRINCIPLE OF REMY DUAL SYSTEM.

principle is used. The battery current is permitted to flow through the primary winding of the armature in such a manner as to supplement such magneto current as is produced at low speeds; or if the magneto is at rest, the armature transforms the battery

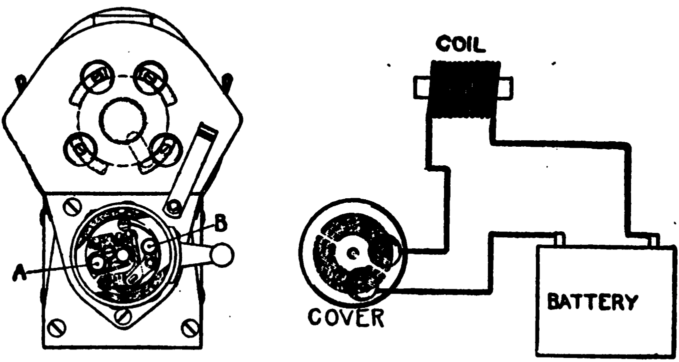


FIG. 81.—PRINCIPLE OF BOSCH DUAL SYSTEM.

current just as a coil would do it. The principle is shown in Figure 81.

The magneto is identical in every way with the independent magneto, except that two half-rings of brass, called **segments**, are attached to the inside of the circuit breaker cover, and that the circuit breaker is

provided with two carbon brushes. One brush, A, is set in the insulated block of the circuit breaker, while the other, B, is located on the circuit breaker disk and is therefore grounded. When the cover is in position the brushes are in contact with the segments.

One terminal of the battery leads to a small coil that has only a few layers of coarse wire; this coil acts like a valve in permitting only a small current to pass through it. From the coil a wire leads to one of the segments, while the other segment is connected to the remaining battery terminal.

With the circuit breaker in the position shown, and the cover in place, brush B will touch segment 1, and brush A will touch segment 2. The circuit breaker being closed, the battery circuit will be complete, for the current can flow from segment 1 and brush B to ground, across the platinum points, and back to the battery by brush A and segment 2. If the armature is turned a trifle, so that

the circuit breaker is open, there will still be a circuit, for the current can then flow from brush B and ground to the grounded end of the armature winding, through the primary winding to the insulated block, and back by brush A as before.

If the armature is at rest with the circuit breaker open, which will be the case with an engine in good condition, the battery circuit may be broken by a press button, and a sparking current will be produced in the secondary winding.

When the armature revolves slowly, as is the case when the engine is cranked, the sudden rush of battery current through the primary winding at the instant when the circuit breaker opens will supplement and strengthen the magneto current, with the result that a very intense spark is produced.

When the engine is running, the armature will be moving fast enough to produce its own spark; the effect will then be to choke

the battery current, so to speak, and the consumption will be little or nothing.

The current from a battery flows constantly in one direction, and is known as a **direct current.** A magneto, on the other hand, gives what is called an **alternating current,** for during one-half of the revolution the current will flow in one direction, and will flow in the opposite direction during the other half of the revolution. If the battery and magneto circuits are connected, the currents will thus supplement each other during one-half of the revolution, and oppose each other during the other half, unless measures are taken to send them in similar directions all the time. In the duplex magneto this is done by the segments on the circuit breaker cover, which form a **commutator.**

During one-half of the revolution of the armature, the magneto current flows from the insulated block across the platinum points to the lever, and during the other half it flows from the lever across the platinum

points to the insulated block. Inasmuch as the cover is stationary, it can be seen that during one-half of the revolution carbon brush A is touching segment 2 and carbon

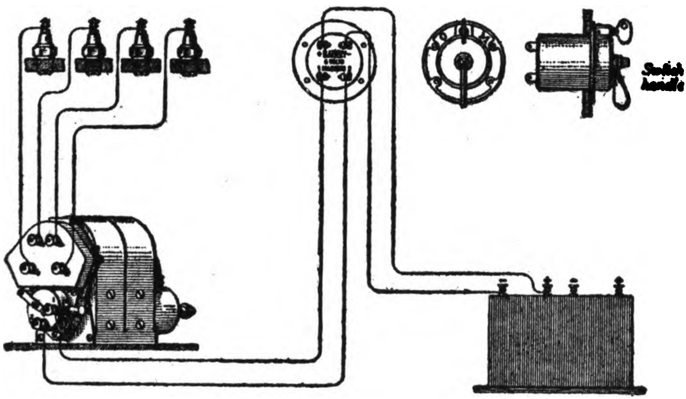


FIG. 82.—CONNECTIONS OF BOSCH DUPLEX SYSTEM.

brush B is touching segment 1, and that during the other half-revolution brush A will be touching segment 1 and brush B segment 2. As the battery current flows constantly to one of the segments, No. 1, for instance, it will flow from that segment to brush A during half of the revolution, and to brush B during the other half. The segments thus

keep the battery current in step with the changes in the flow of magneto current.

The connections of the duplex system are shown in Figure 82, and they must be followed exactly. If the battery connections are reversed, the battery current will oppose the magneto current instead of supplementing it, and no sparks will be produced. With reversed connections, a spark can be produced by the press button when the magneto is at rest, for then there is no magneto current to oppose the battery current. The engine may start on the spark, but will not continue to run; this condition is an indication that the battery connections are reversed.

CHAPTER XII

SPARK PLUGS, CABLES, TERMINALS, AND COUPLINGS

IN order that a spark may be formed, the circuit provided for the sparking current must include an air space; the size of this space should be such that the pressure will force the current across it. This space is located in what is known as the **spark plug.**

The spark plug is formed of two pieces of metal, the ends of which are brought sufficiently close together to form the proper gap. These two pieces of metal or electrodes are held in position and are prevented from touching by some form of insulating material.

An illustration of a spark plug, together with a section showing its interior construction, is indicated in Figure 83. The outer

part or shell is made of metal, and is provided with a screw thread that permits it to

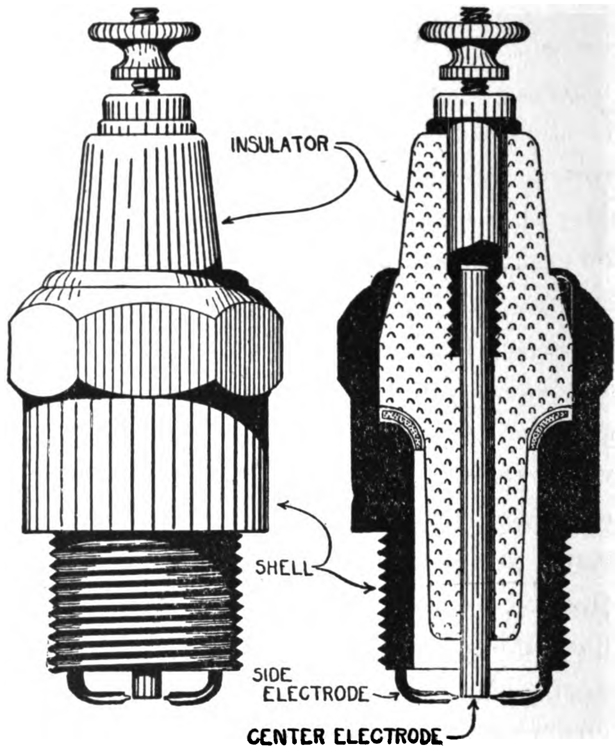


FIG. 83.—SPARK PLUG.

be screwed into an opening in the cylinder. Within the shell is the insulator, and

through the center of this passes the second or center electrode, which terminates at one end with a binding nut, at which is made the connection with the sparking circuit. The current passes from the center electrode to the shell, which forms the outer electrode, or from the shell to the center electrode. The outer shell being in contact with the metal of the engine, the current can pass from one to the other, and thus to ground.

The insulator is subjected to the intense heat and pressure existing in the cylinder, and must be of a material that will resist injuries from these causes. The most satisfactory insulating material is a composition known as **steatite**, because in addition to its other advantages it is practically unbreakable. Porcelain and mica are also very frequently used.

An electric current will find it easier to pass between two pointed pieces of metal than between round or flat ends. Spark plugs constructed in this manner will have

an advantage over those of which the electrode ends are flat or rounded in permitting the current to pass at lower pressure; an engine may thus be started at a lower cranking speed on the magneto than will be possible when the electrodes are blunt. A so-called electric spark is in reality not visible electricity, but is composed of tiny particles of metal torn off and vaporized by the intense heat of the current. The electrodes of a spark plug will thus burn away in time, and the gap will be increased. It has been found that nickel or its alloys will permit the formation of a good spark, while at the same time they will resist the burning effect longer than any other material that it is practical to use.

The parts of a spark plug should be assembled in such a manner as to prevent the possibility of leakage of compression. When the parts of a spark plug are screwed together they should be inspected at frequent intervals to guard against this.

The gap provided between the electrodes will vary from 1-50 inch to 1-32 inch, according to the characteristics of the engine. A wide gap presents more resistance to the

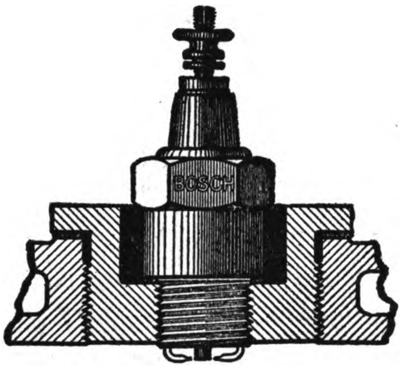


FIG. 84.—CORRECT LOCATION OF SPARK PLUG.

passage of the current than a small one, and if it is difficult to start an engine on the magneto the cause will frequently be located as lying in too great a spark plug gap.

It is almost invariably the case that the spark plug is set in the cap of the inlet valve or as close in the inlet valve as possible, in order that the spark plug points may be sur-

rounded by fresh mixture. A spark plug located in the exhaust valve cap of a T-head engine may cause misfiring because the fresh mixture does not reach it.

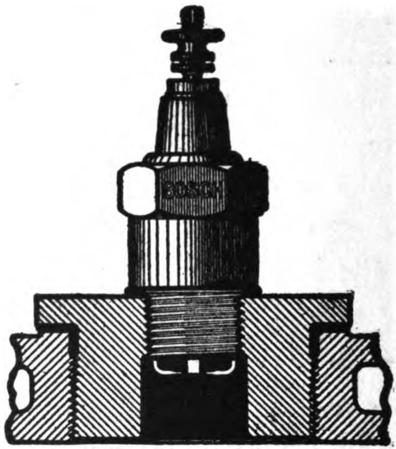


FIG. 85.—POCKETED SPARK PLUG.

The spark plug should be so located that the sparking points are actually plunged into the mixture, as indicated in Figure 84. If the valve cap is so thick that the spark plug points do not project, as is indicated in Figure 85, the cavity or pocket will contain a mixture of fresh and burnt gases. Under

such conditions a greater advance will be required than is justified by the engine size, because of the slowness with which the flame that starts at the spark plug will reach the main body of mixture. When such a condition exists, the running of the engine will be greatly increased by drilling out the valve cap to permit the spark plug to be inserted in it deeper, as shown in Figure 84.

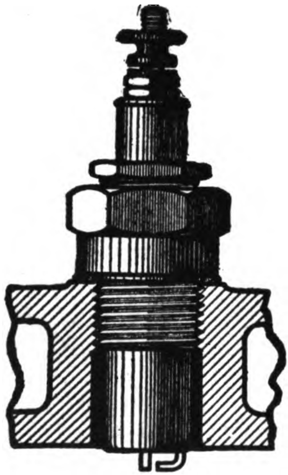


FIG. 86.—EXTENDED SPARK PLUG.

In many engines the spark plug passes through the cylinder head or wall, which is of considerable thickness. A condition of this sort cannot be remedied by the user of the engine, and in order to plunge the sparking points into the fresh mixture it will be necessary to use a spark

plug made with an extension below the threaded portion, as shown in Figure 86. The results from this are not altogether satis-

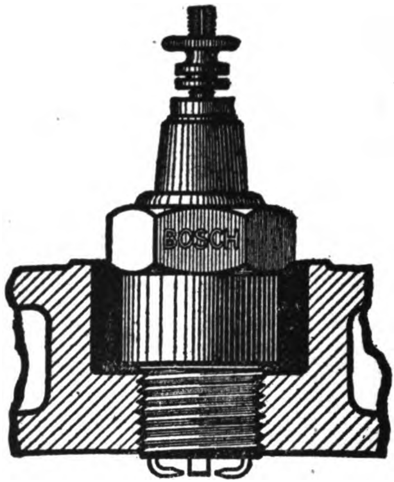


FIG. 87.—CORRECT LOCATION OF SPARK PLUG.

factory, because the heat absorbed by the extended end of the plug cannot pass off to the water jacket sufficiently rapidly, and overheating is liable to result. The effect of this will be the warping of the central electrode and a consequent alteration in the size of the spark gap; or if the sparking points are slen-

der they will become incandescent and will ignite the incoming fresh mixture before the spark passes.

A properly placed spark plug for such an engine is indicated in Figure 87. In this case the opening has been made of sufficient size to permit the spark plug to be set into it far enough to allow the sparking points to come into contact with the mixture.

It is poor economy to invest in a badly constructed and inefficient spark plug. The cost of a high-grade plug is not excessive, and its use will render the engine more efficient and reliable.

Cables of two sizes are in use on an ignition system, one, the low-tension cable, being comparatively lightly insulated because it carries the low-pressure current from the battery or from the primary circuit of the magneto, while the other, the high-tension cable, conducts the sparking current from the distributor to the spark plug.

The insulation of the high-tension cable

must be of such quality and thickness that it will be easier for the current to make its circuit through the spark plugs than to break through the insulation, and thus make a new circuit for itself.

In a high-tension cable soft rubber of the best quality will give better satisfaction than any other. A cable with very thick insulation will retain the current, but it will be likely to produce a condition that will interfere with the operation of the engine.

Everyone has experienced the electrifying of a hard rubber comb when combing the hair on a cold morning; the passage of a high-tension current, particularly that produced by a true high-tension magneto, will have a similar effect upon the insulation of the cable through which it passes. The result will be what may be termed a **static charge** on the surface of the insulation; when the charge becomes sufficiently intense, the electricity thus collected will pass to ground. The thicker the insulation the greater will be

its surface, and consequently the greater will be the opportunity for the collection of the charge.

If the cable is held in metal supports, which are attached directly to the engine, this charge will pass off to ground without having any effect, but if the cables are led through a tube made of fiber or other insulating material, as is frequently the case, this charge will go to ground across the electrodes of the spark plug, forming a spark as it passes. This second spark will normally follow the passage of the ignition spark and will do no harm.

When the cables are long, so that the surface is considerable, the insulation may become so highly charged that the electricity will pass across the electrodes of the spark plug before the ignition spark passes. It will then cause the preignition of the charge and result in backfiring.

The most satisfactory results will be attained when the ignition cables are short,

and when they are supported in such a way that the electricity collecting on the surface of the cable insulation may pass directly to the metal of the engine. This is assured by supporting the cables in metal cleats. The discharge of this electrical charge is frequently mistaken for defective insulation.

The end of the cables should always be provided with metal terminals. When the insulation is stripped from the wire and the wire strands are twisted together and then applied to a binding post, there is great liability that a stray strand of the wire will permit a short circuit to some neighboring piece of metal. The use of a terminal not only prevents this, but protects the cable from breaking at the point where the wire emerges from the insulation.

It is frequently the case that the magneto is driven through some form of coupling or universal joint. With quiet running modern engines the magneto is frequently blamed for making a noise that in fact originates in the

coupling. A coupling may feel tight and may appear to have no lost motion, but may nevertheless be the cause of an annoying rattle. At certain points in its revolution a magneto requires more power to turn the armature than is necessary at other points, because of the constant change in the flow of magnetism. This has the effect of checking the rotation of the armature twice in each revolution, and this intermittent resistance to turning will cause a rattle in the coupling unless it is constructed in such a manner that a spring action absorbs the lost motion.

CHAPTER XIII

TRANSMISSION

THE **transmission** of an automobile consists of those parts that transmit to the driving wheels the power developed by the engine.

THE CLUTCH

Because a gasoline engine must be in operation before it can deliver power, a **clutch** is provided by means of which it may run free or be so connected that it drives the car, one of its two chief parts being attached to the engine and the other to the transmission. When the two parts are in contact, the transmission is driven, and when separated, the engine and transmission are independent of each other, and may be stationary or in motion. A clutch must be of such a nature that it does not apply the power of the engine in-

stantly, but gradually, so that the car starts slowly and without jerking. If the power were to be applied suddenly, the effort of starting the stationary car would either overcome the momentum of the engine and stop it, or would jerk the car into such sudden motion that it might be badly wrenched. By making the clutch so that it is permitted to slip when first applied, the part that is driven is gradually brought to the speed of the part that drives, when slipping ceases and the two make firm contact.

The most usual form of clutch is the **friction cone**, in which the fly wheel of the engine is utilized as the driving part, the rim being broad and thick, with its inner side funnel-shaped, or beveled. A metal **cone** that fits the bevel is carried on the end of a shaft of the transmission, the shaft at this point being square, to fit a square hole in the hub of the cone. This arrangement permits the cone to slide along the shaft while always revolving with it. When the cone is pressed

to a seat in the fly wheel, which is accomplished by means of a heavy coil spring, the friction between its leather-covered surface and the surface of the fly wheel causes the two parts to revolve together, and by its fit on the square shaft the transmission is set in motion, and through that the car. The clutch is thrown out of contact by means of a foot pedal that acts on a ring fitting in a groove around the hub of the cone; when the pedal is released, the spring forces the cone to its seat (Fig. 88). In order to support it, the end of the shaft carrying the cone projects into the hub of the fly wheel, where it rests in a bearing, this arrangement in no manner preventing the two parts from acting independently of each other.

In the **reversed type** of friction-cone clutch a funnel-shaped ring is bolted to the rim of the fly wheel and forms the seat, the cone fitting inside of it (Fig. 88). Depressing the pedal moves the cone toward the fly wheel instead of away from it, as in the regular

type, and while there is no difference in the effect of one as against the other, the reversed type is more compact.

The **multiple-disk clutch,** which is rapidly coming into use, depends on the friction between the flat surfaces of metal when pressed together. An experiment illustrating this is to place a silver dollar between two half dollars, and to press them together between the thumb and finger. It will be found that a light pressure is sufficient to produce friction that will make it difficult to revolve the large coin between the smaller ones.

The parts of a simple form of multiple-disk clutch, as shown in Figure 89, are a **flange** on the engine shaft, a smaller flange with a square-hole, square-shaft arrangement on the transmission shaft, and large and small **rings** placed alternately. The large rings are driven by the large flange, fitting loosely on pins, or **studs**, projecting from it, and the small rings are similarly attached to

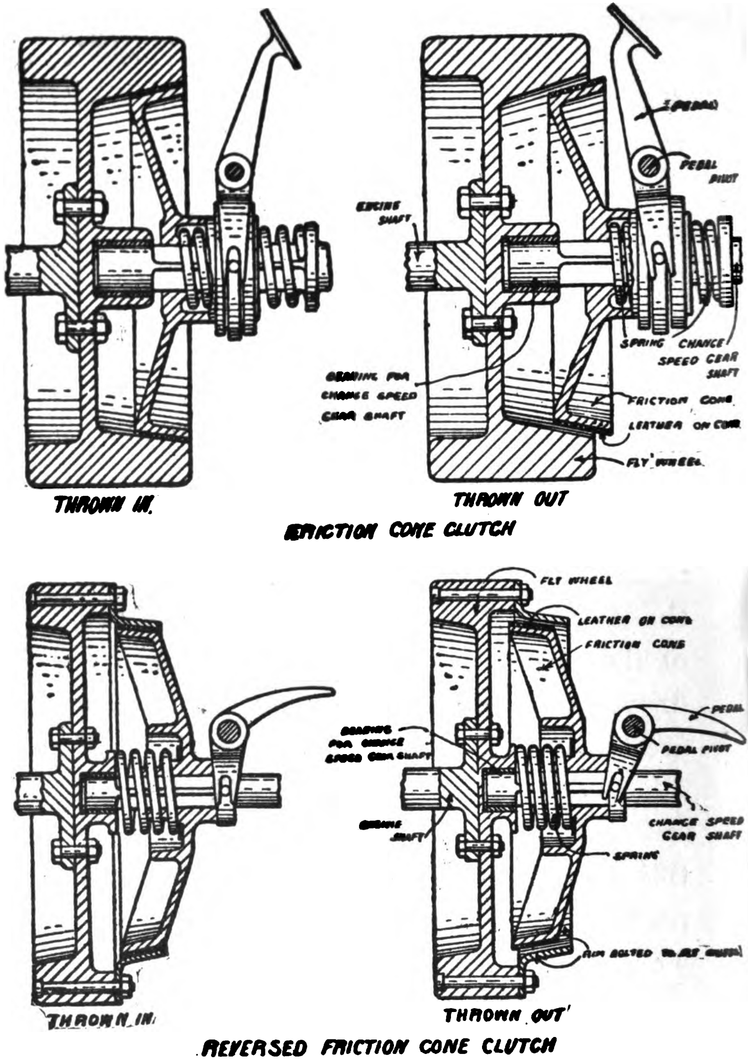


FIG. 88.—FRICTION CONE CLUTCHES.

the transmission shaft. The openings in the large or driving rings are large enough to contain the studs carrying the small rings, so that when the parts are assembled the outer surfaces of the small or driven rings are in contact with the inner surfaces of the driving rings. A heavy coil spring is arranged to press the small flange toward the flange on the engine shaft, binding the rings that it carries between the driving rings, and the latter are often faced with leather to increase the friction between them. When the small flange is released from the pressure of the spring by depressing the pedal, the driving and driven flanges with their rings are independent of each other, and the engine may run free while the transmission shaft is stationary or revolving. A clutch of this type is incased and runs in oil, which prevents the rings from gripping suddenly; when the pressure of the spring is applied, the oil is gradually squeezed out from between them, and the slipping of the driving

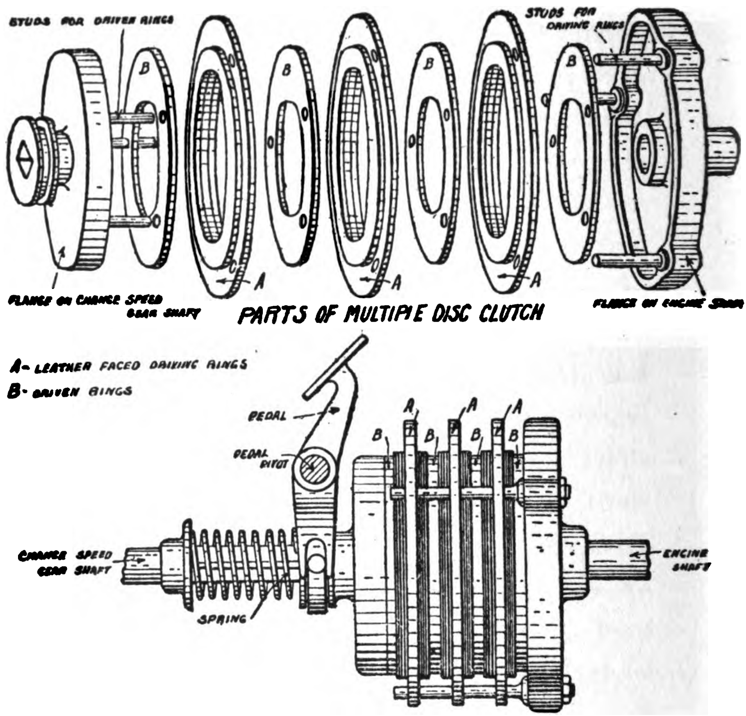


FIG. 89.—MULTIPLE DISK CLUTCH.

and driven rings is reduced as they are forced into contact.

An **internal-expanding** clutch consists of a broad ring, or **drum**, against the inner surface of which are two pieces of metal shaped to fit. The pieces of metal, or **shoes**, are pivoted together at one end so that they may be moved in or out, after the manner of the handles of a pair of scissors; when open they bear against the inside surface of the drum, and when closed they are free from it. The drum is attached to the engine shaft and the shoes to the transmission shaft, the friction between them being so great that the transmission shaft is carried around as the drum revolves. The shoes are kept in contact with the drum by a coil spring, the depression of a pedal releasing them from its pressure.

CHANGE-SPEED MECHANISM

The **change-speed mechanism**, to which the clutch transmits the power of the engine, is

to the engine what a block and tackle is to a man who lifts a heavy weight, and is necessary because of the varying resistance to the movement of the car in traversing steep, rough hills and smooth avenues. A change-speed mechanism may be defined as an arrangement by which the relative number of revolutions of the crank shaft and driving wheels may be altered to suit conditions. If the driving wheels revolve but once while the crank shaft makes twelve revolutions, the car will move at one sixth the speed that it would have if the wheels revolved once to every two revolutions of the crank shaft, but it will have six times the ability to overcome the resistance presented by a hill or sandy road.

If a gasoline engine were so connected that the relative number of revolutions of the crank shaft and wheels could not be changed, a slowing down of the car through the resistance presented by a rough hill would slow the engine to correspond, and as speed

is an important factor in the power that the engine delivers, it would be prevented from doing the work of which it is capable at the time when it was most necessary. By means of the change-speed mechanisms in most general use, the number of revolutions of the crank shaft to one of the wheels may be from two to eighteen, the former giving the car high speed over a smooth road, and the latter slow speed, but greater ability to overcome hills and heavy roads.

To attain this result, gears are used. If two gears having the same number of teeth are in mesh, they will make the same number of revolutions, and the force with which the driven gear will revolve will be the same as that of the driving gear, less the friction of the teeth. If the driven gear has twice the number of teeth of the driving gear, it will revolve at half the speed, but with twice the force.

The forms of change-speed mechanism most largely used are based on this principle,

which is so applied that the gear driven by the engine may be in mesh with a gear that has many more teeth and revolves much slower in consequence, or a gear that has possibly one and a half times the number of teeth, or a gear that has the same number of teeth, and therefore revolves at the same speed. The **sliding-gear** mechanism takes its name from the arrangement by which the changes in the combination of gears are effected by sliding them along a shaft, to mesh with other gears on a shaft driven by the engine.

The driver changes the gears by moving a lever that in the **progressive type** moves forward by degrees to move the car on the slow speed, the intermediate speeds, and the high. A typical arrangement of the progressive type of sliding change-speed mechanism is shown in Figure 90. The power of the engine is transmitted to a short, hollow shaft, called a **sleeve** (A), which carries a gear (B) that is in permanent mesh with a gear

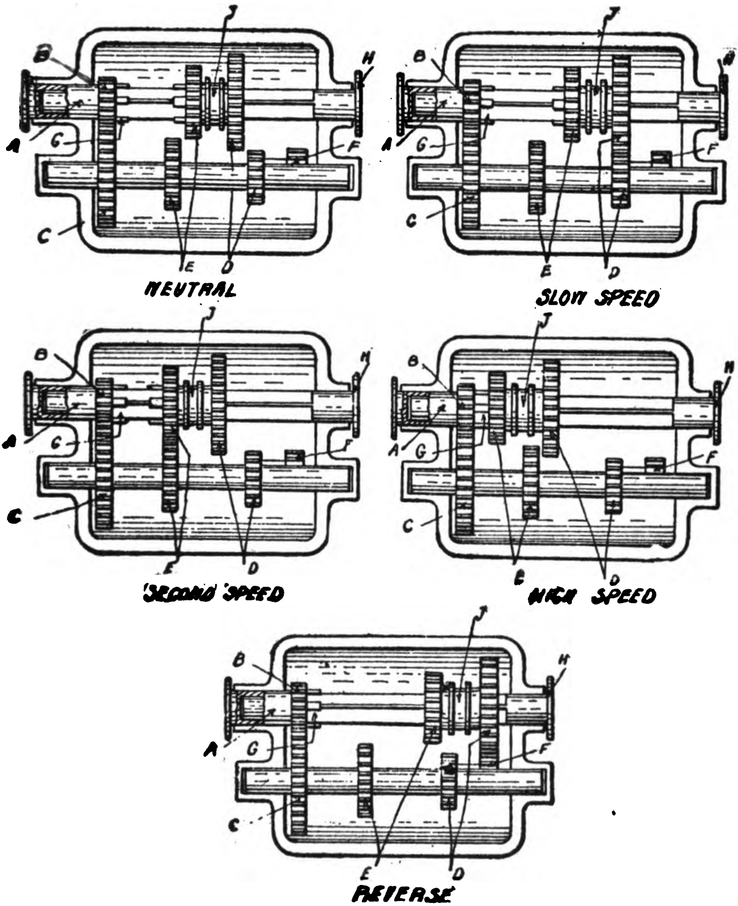


Fig. 90.—Sliding Gear—Progressive Type. A, sleeve driven by engine; B, gear on sleeve; C, gear on countershaft; D, low-speed gears; E, second-speed gears; F, idler for reverse; G, clutch for high speed; H, connected to rear wheels; J, gears sliding on square shaft.

(C) on the end of the **counter-shaft.** Parallel to the countershaft is another shaft, one end of which is held in a bearing in the hollow sleeve; while the sleeve supports this shaft, the two may revolve independently of each other. The second shaft is square, or of such a construction that while the two gears that it carries may slide along, they revolve with it. The gears on the square shaft are of different sizes, and in sliding on it come successively into mesh with gears carried on the countershaft. Because of the gears between them, the countershaft revolves when the engine revolves the sleeve; but the speed of the square shaft depends on the combination of gears in mesh between it and the countershaft. When the sliding gears are in such a position that they are not in mesh with the countershaft gears, the square shaft is independent of the countershaft, and may revolve or be stationary, the gears then being in the **neutral position.** When the sliding part is moved so that its

largest gear is in mesh with the smallest of the countershaft gears (D), the square shaft will revolve at a slower speed than the countershaft, because its gear is larger than the one driving it. Again sliding the moving part will separate these gears, and bring the next pair (E) into mesh, the square shaft then moving at a higher speed, but still slower than the countershaft because of the difference in the size of the gears. Sliding the moving part still farther along the shaft will disengage the **second-speed** gears and engage the **high speed**, in which the square shaft revolves at the speed of the sleeve and crank shaft, this being effected by locking the moving part to the sleeve by means of a clutch (G). This clutch consists of several fingers projecting from the moving part, corresponding to the spaces between similar fingers on the end of the sleeve. The locking together of the square shaft and sleeve gives what is known as the **direct drive**, which is of comparatively recent development; some

designs of sliding gears still use a third pair of gears which, being of the same size, give the square shaft the speed of the crank shaft. By the use of the direct drive, the power of the engine is directly applied to the square shaft, avoiding the loss that occurs through the friction of the teeth of the gears.

The revolution of the square shaft is transmitted to the driving wheels, the speed of the car therefore corresponding to the speed at which the square shaft is driven by the gear combinations between it and the countershaft. To obtain the **reverse**, which enables the car to be backed without reversing the engine, a third gear is introduced between the low-speed gears of the square shaft and countershaft. When two gears are in mesh, they revolve in opposite directions, but when one of them is in addition meshed with a third gear, the first and third will revolve in the same direction, and opposite to the direction in which the middle gear revolves. When the car is going forward, the

square shaft and countershaft revolve in opposite directions, but when the reverse gear is introduced between them, the square shaft is revolved in the same direction as the countershaft, reversing the rotation of the driving wheels.

The ends of the teeth of the gears are chisel-shaped, instead of being flat, as in ordinary gears, so that they will go into mesh easily.

The greatest economy in the operation of a gasoline engine results from its running at as nearly constant a speed as possible, and the gear is therefore changed when the resistance of the road to the movement of the car decreases the speed of the engine, or permits it to increase.

In the progressive change speed gear it is necessary to engage and disengage the intermediate gears in passing from low to high, or from high to low. The difficulties encountered in this operation have caused the abandonment of the progressive gear and

the adoption of a construction that makes it possible to pass from neutral to any desired speed. This construction is known as the **selective type** of sliding change speed gear.

The selective change speed gear is shown in Figure 91, and its control differs from that of the progressive type described in that the lever has only a short movement forward and back, and in addition may slide endways. To the lower end of the lever is attached a shaft that rocks in its bearings as the lever is moved forward or back, and slides lengthways when the lever is moved toward or away from the car.

The arrangement of the countershaft and square shaft is the same as in the progressive type, but there are two sets of sliding gears instead of one, and these are moved by means of arms that extend from rods sliding in bearings at the side of the gear case. When these rods are slid endways, the gears attached to their arms slide on the square shaft to correspond, and go in or out of mesh with

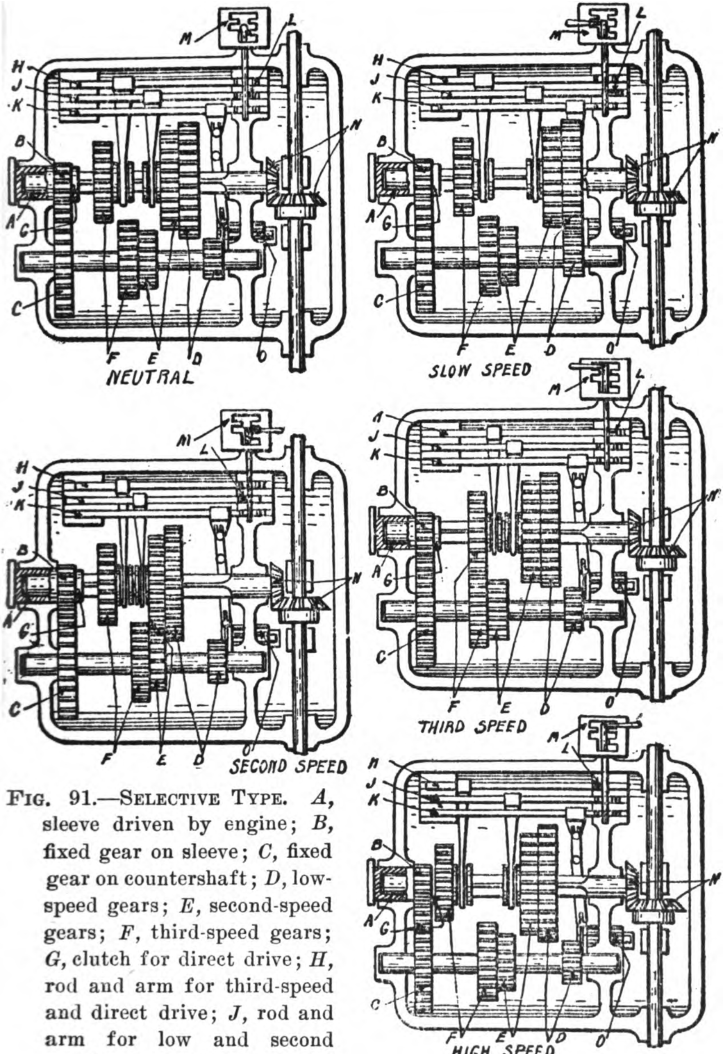


FIG. 91.—SELECTIVE TYPE. *A*, sleeve driven by engine; *B*, fixed gear on sleeve; *C*, fixed gear on countershaft; *D*, low-speed gears; *E*, second-speed gears; *F*, third-speed gears; *G*, clutch for direct drive; *H*, rod and arm for third-speed and direct drive; *J*, rod and arm for low and second **speeds; *K*, rod and arm for reverse; *L*, rocking shaft finger in groove; *M*, guide plate and control lever; *N*, bevel gears on square shaft and jack shaft; *O*, idler gear for reverse.**

the countershaft gears. Across the ends of these rods are grooves, which when the gears are in the neutral position are in line with the rocking shaft attached to the control lever. From the inward end of the rocking shaft a finger (L) projects downward into the groove; when the grooves are in line, the rocking shaft may be slid endways, the finger passing from one groove to the next without affecting the rods. When the shaft is rocked, however, the finger in engaging one of the grooves slides the rod endways, shifting the gears controlled by its arm. Moving the control lever into such a position that it may enter the middle slots of the guide plate (M) slides the rocking shaft so that its finger projects into the groove of the central sliding rod (J), and if the control lever is then pushed forward so that it enters the front half of the slot, the sliding rod will be moved by the finger in the opposite direction, and the low-speed gears (D) will be brought into mesh. Bringing the lever back to the cen-

tral position will separate the gears, and moving it to the back half of the slot will slide the same gears in the opposite direction, meshing the second-speed combination (E). Moving the control lever outward so that it is in line with the outside slot brings the finger into the groove of the sliding rod (H) that moves the third and high speeds (F and G), the latter being direct drive, and the reverse is obtained through the movement of the sliding rod (K) that is engaged by the finger when the control lever is in the inside slot. The movement of this rod brings a third gear (O) into mesh with the low-speed gears on the square shaft and countershaft, and the rotation of the countershaft is reversed. The arrangement of the control lever and its parts is shown in Figure 92.

While this type is in general use, the gears are often so arranged that the direct drive combination is reached when the control lever is in the third-speed position, the gears meshed by the fourth-speed position driving

the square shaft at a still higher speed. This high speed can only be used for running under the best road conditions.

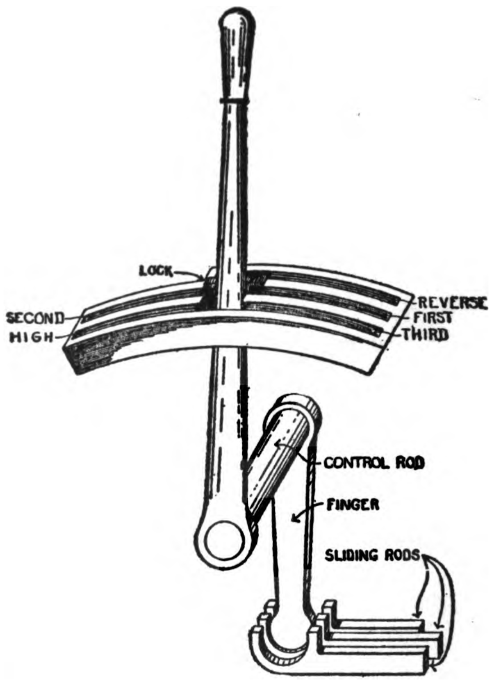


FIG. 92.—ACTION OF SPEED CONTROL LEVER.

The advantages of the selective type over the progressive are the shorter movements

of the control lever and the ability to pass from one speed to any other without the necessity of first meshing and unmeshing those between, or, in other words, there is a neutral position between every combination of gears, and from neutral any desired combination may be obtained directly without reference to the others.

In starting up a car fitted with either of these types of change-speed mechanism, it is necessary to withdraw the clutch before sliding the gears, and this is also necessary in changing from one combination to another. The square or corresponding shaft of a change-speed mechanism is always connected with the driving wheels, and is at rest when the car is standing. With the engine running, the countershaft will be revolving, and it will obviously be difficult to slide the stationary gear into mesh with a gear that is revolving. When the clutch is withdrawn, the countershaft moves only through momentum, and will be brought to a stop by the

contact of the teeth of the sliding gear as that is moved against it, the two then easily going into mesh. The clutch is then thrown in slowly, and will bring the speed of the countershaft to the speed of the crank shaft.

When the car is moving, sliding the gears without first withdrawing the clutch will bring together two gears that are revolving at different speeds, and as it is necessary for them to be rotating equally in order that they may mesh, either the speed of the car must be changed to bring the speed of the gear on the square shaft to that of the countershaft gear, or the speed of the engine must be changed to bring the countershaft gear to the speed of the gear on the square shaft. If the change is from a low to a higher speed, the countershaft will be moving much faster than the square shaft, and their gears being brought into contact will result in the slowing of one and speeding up of the other until the speeds are the same, but in so doing the ends of the teeth will grind against each

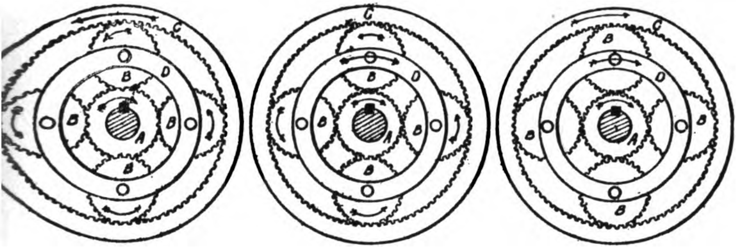
other, resulting in the wear of the chisel-pointed ends, if not in the breaking of the teeth. Withdrawing the clutch obviates this difficulty, for it frees the countershaft, permitting its gear to take the speed of the square-shaft gear without wear or damage, and when the change is made, the slow engagement of the clutch brings the speed of both to that required by the crank shaft.

CHAPTER XIV

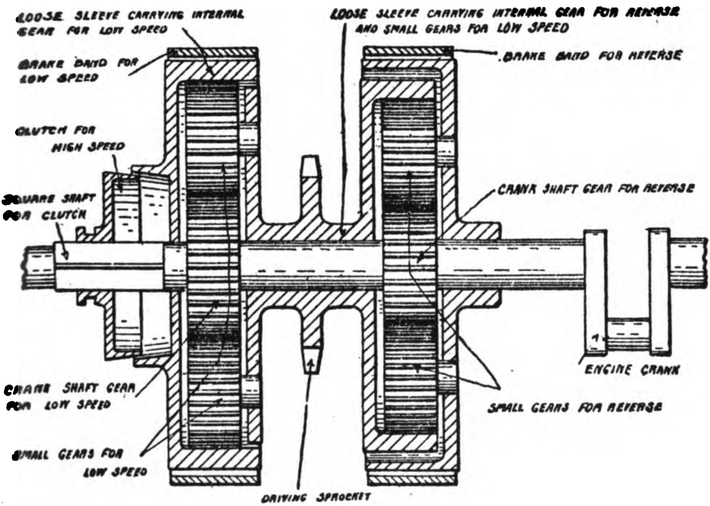
TRANSMISSION—(*Continued*)

WHILE the **planetary type** of change-speed mechanism, which is in extensive use for runabouts and light commercial wagons, also employs gears, their arrangement is along different lines. The first three diagrams in Figure 93 serve to illustrate the principle.

The gear A in these diagrams is attached directly to the crank shaft, and in mesh with it are four other gears (B) of the same size. Surrounding them is an **internal gear** (C), this being a ring with teeth cut on its inner face, the four gears meshing with it. The shafts, or **studs**, on which the four gears revolve are supported by a metal ring (D), which maintains the gears at equal distances from each other. The first diagram shows the mechanism in the reverse position, for



PRINCIPLES OF PLANETARY GEAR TRANSMISSION



SECTION PLANETARY GEAR TRANSMISSION

Fig. 93.—Planetary Type.

driving the car backward, the car being driven by the internal gear. To have the internal gear revolve in the direction opposite to that of the crank shaft, as is necessary, the ring supporting the four gears is held stationary, with the result that as the crank-shaft gear revolves the four gears are revolved on their studs. As these gears are in mesh with the internal gear, that is revolved, and moves in the same direction as the four gears and in the opposite direction to the crank shaft.

For the low-speed forward, the ring is released and the internal gear held stationary, the car now being driven by the ring instead of by the internal gear. If the four gears were free from the internal gear, they and their ring would revolve with the crank-shaft gear without rotating on their studs, but being in mesh with the internal gear, they roll around it as a wheel rolls along the ground, rotating on their studs. A simple experiment that will illustrate this motion is to crook

the forefinger around a napkin ring or similar object, placing a pencil between it and the finger, and revolving the ring with the other hand. The finger being stationary, the pencil, which is revolved in the opposite direction to the ring, will roll along it. In this the napkin ring represents the crank-shaft gear, the pencil one of the four gears, and the finger the internal gear. As the four gears roll around, the ring moves also, for it is carried by the studs on which the four gears revolve. If each of the four gears has fifty teeth, and the internal gear two hundred teeth, each gear must make four revolutions in order to roll around the internal gear to the point where it started. The crank-shaft gear also having fifty teeth, it revolves at the same speed, and as four revolutions of the four gears are necessary in order that they may roll completely around the internal gear, the crank-shaft gear will make four revolutions in the same time. The ring moves with the four gears, and revolves

once around the crank shaft in the same time. As the car moves according to the rotation of this ring, it will go at one quarter the speed that it would make if the wheels were directly connected with the crank shaft instead of with the ring.

For the high speed, the internal gear and the ring are locked to the crank shaft so that all revolve together, the wheels being driven by either the ring or the internal gear.

In these diagrams the drive of the wheels is supposed to be shifted from the internal gear to the ring, which is not a practical arrangement, and the planetary change-speed mechanism as applied to an automobile is shown in the lower diagram in Figure 93.

In this there are two sets of crank-shaft gears, gears and rings, and internal gears, one set being for the reverse and the other for low and high speeds. Between the two crank-shaft gears is a loose sleeve, one end of which forms the internal gear for the reverse, and the other end the ring supporting

the studs on which revolve the four gears for the low speed. The sprocket for the chain drive to the rear axle is carried on this sleeve. Two more loose sleeves are on the shaft, one forming the ring on which revolve the four gears for the reverse, and being extended to form a brake drum outside of the internal gear, and the other carrying the internal gear for the low-speed combination, its outside face serving as a brake drum.

To obtain the reverse, a brake band is tightened on the drum of the reverse combination, which holds stationary the ring supporting the four gears, giving the result shown on the first diagram of the four gears revolving on their studs, and rotating the internal gear in the direction opposite to that of the crank shaft. The sleeve bearing the sprocket is thus revolved, and the car backs.

For the low speed, the reverse brake band is loosened, and the internal gear of the low-speed combination held stationary by the tightening of the brake band surrounding its

drum. The revolution of the crank-shaft gear causes the four gears to revolve on their studs and to roll around the internal gear, revolving the ring and the sleeve bearing the sprocket, which now turns in the direction opposite to that resulting to the application of the reverse, or in the same direction as the crank shaft.

For the high speed, a clutch is engaged that locks the internal gear to the crank shaft, and the four gears then being held between these two are carried around with them, and the sprocket rotates accordingly. When this combination is used, none of the gears are in motion, all revolving with the crank shaft, but not on their studs.

The planetary change-speed mechanism gives excellent results for light work, but having only two speeds forward is not adapted to high-powered cars. As the speeds result from the tightening of brake bands on the drums, there is no danger of damaging the gears by mishandling, for the

brakes will slip before the teeth will give way. The brakes, which are leather-lined strips of steel, require attention from the wearing of the leather, and the slipping that results from oil working in between them and their drums. No foot clutch is necessary, for the tightening and loosening of the brake bands are controlled by a lever; in some designs, the reverse is applied by means of a foot pedal, and this may be used in braking the car.

FINAL DRIVE

From the change-speed mechanism the power is passed to the driving wheels by the **final drive.**

In the most usual construction the engine is so placed that the crank shaft is at right angles to the axle, and it is therefore necessary to change the direction in which the power acts, which is done by means of **bevel gears.** In ordinary spur gears the teeth are parallel to the shaft, and the two shafts that

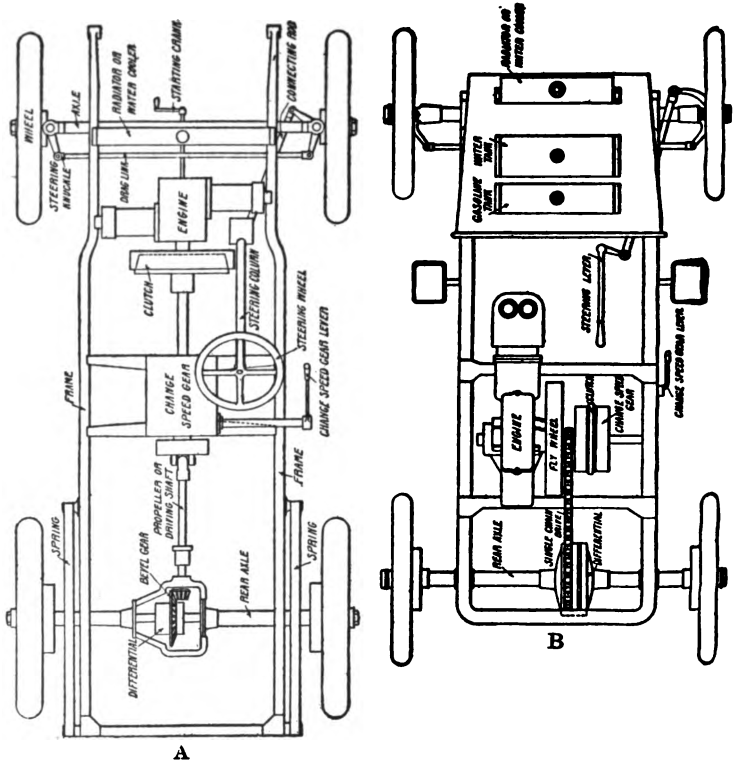


Fig. 94.—A, Propeller or Driving-shaft Drive; B, Single-chain Drive.

carry them are parallel, while in bevel gears the teeth are at an angle, and the shafts may be at right angles to each other. In Figure 94 the diagram of the **single-chain drive** illustrates a car in which the engine is in the center of the frame, and as the crank shaft is

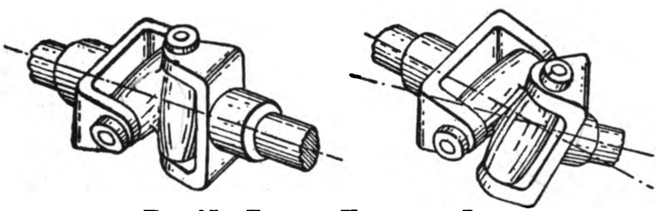


FIG. 95.—TYPICAL UNIVERSAL JOINT.

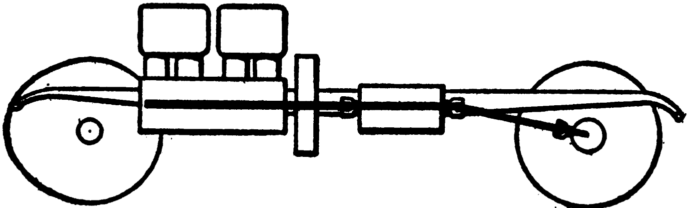
parallel to the axle, the power may be directly applied. In the illustration of the **propeller** or **driving-shaft drive** the crank shaft is at right angles to the axle, and the power is turned by means of the bevel gears at the rear axle.

The single-chain drive can only be used for light cars, and is usually applied in connection with a change-speed mechanism of the planetary type.

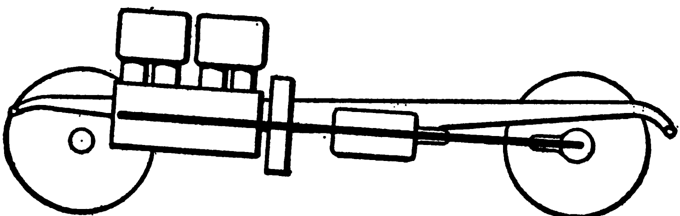
The propeller-shaft drive requires the use

of **universal joints**, which are devices that permit one shaft to drive another, even though they are at an angle with each other. A typical universal joint is illustrated in Figure 95. The ends of the shafts bear yokes, the ends of which are pivoted to a block of metal of + shape. When the two shafts are in line, the joint will force one to rotate with the other, and this will not be prevented if the two are out of line, for then the pivots will act, the + swinging on its pivots in the yokes.

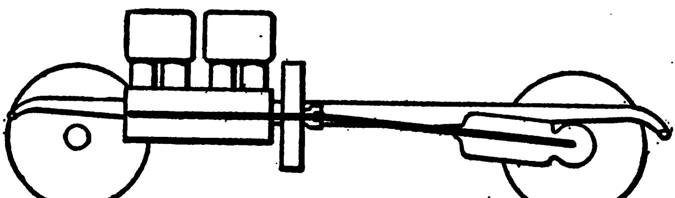
The change-speed mechanism is carried on the frame of the car, and is therefore supported by the springs, but the axle end of the driving shaft follows the axle as that follows the inequalities of the road. One end of the propeller shaft is therefore comparatively stationary, while the other is in constant motion, and if the shaft were inflexible it would be jammed in its bearings and twisted out of line. This is prevented by the universal joints with which the shaft is pro-



DRIVE THROUGH UNIVERSAL JOINTS



"STRAIGHT LINE" DRIVE



GEAR BOX ON REAR AXLE

FIG. 96.—TYPES OF SHAFT DRIVE.

vided, there being one and often two in the shaft, and usually one between the clutch and change-speed mechanism.

The single-chain and driving-shaft drives require the use of a **live axle**, which is an axle that revolves with the wheels. The simple type of live axle consists of the shaft to which the wheels are attached, and the **housing** that contains and supports it (Fig. 97). This axle is continuous, and usually has square ends that fit into the square hubs of the wheels so there may be no slipping. The second diagram in Figure 98 shows a live axle of the **floating** type, in which the revolving part serves only to turn the wheels. The housing is extended, and the wheels run on its ends, the driving part projecting beyond the housing and having square ends that are secured to the outside of the hubs by square caps. The wheels thus run on the housing, which takes the weight of the car from the driving part. A live axle must be divided into two parts in order that a differential

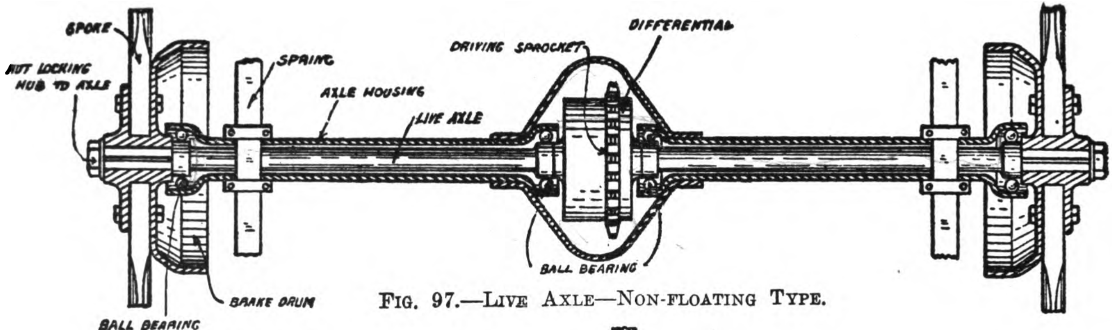


FIG. 97.—LIVE AXLE—NON-FLOATING TYPE.

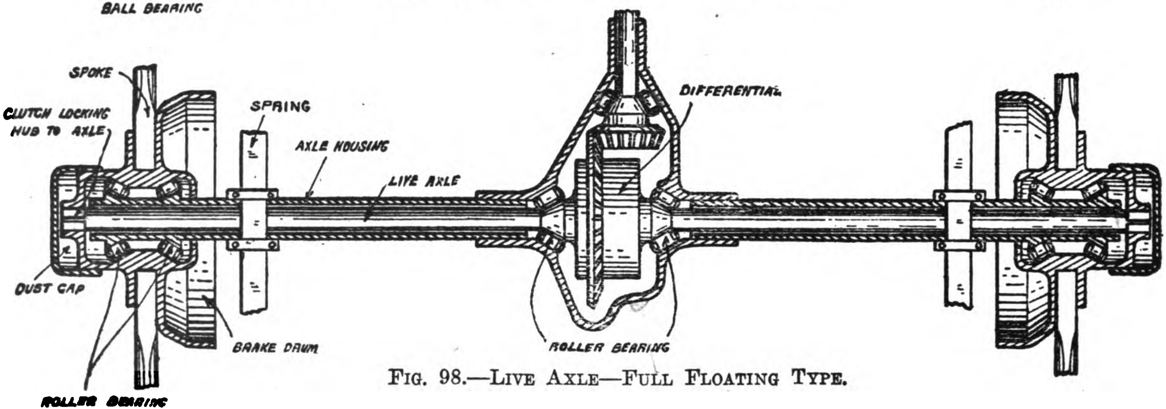


FIG. 98.—LIVE AXLE—FULL FLOATING TYPE.

gear may be fitted, and the housing must therefore be strong enough to support the weight and prevent sagging. The efficiency of a bevel gear is greatly reduced if the teeth are not in their exact mesh, and sagging of the axle will throw them out to such an extent that they will be noisy, and wear rapidly. The floating type of live axle, in relieving the driving part of the weight, has a great advantage over the simple type, and is in general use.

With the driving-shaft drive it is necessary to use a **torsion rod**, which extends from the gear case, or a crosspiece of the frame, to the rear axle. The necessity for this is the tendency of the driving bevel gear to roll around on the driven bevel gear rather than to revolve it. If it were not for the torsion rod, there would be a continual strain on the parts because of the tendency of the axle housing to revolve around the axle, instead of the axle being revolved inside of the housing. The torsion rod has a flexible joint at

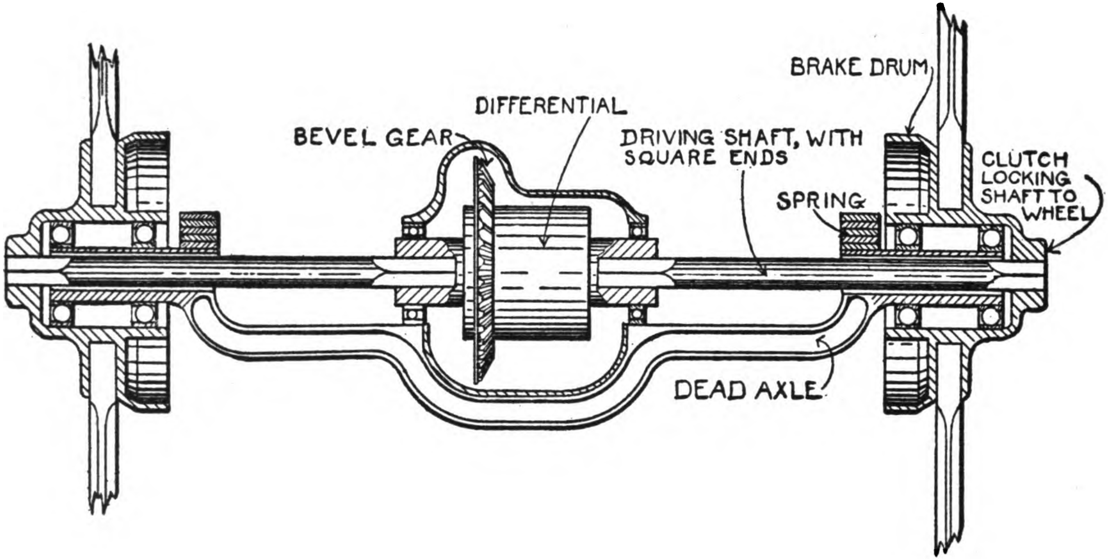


Fig. 99.—Dead Axle with Driving Shaft. Axle supports bevel gear and differential. The driving shaft is supported in bearings at the differential end, and drives the wheels through clutches in the hubs.

one end, that permits it to give as the axle follows an uneven road surface, but it retains the housing in the correct position, preventing the bevel gears from getting out of line. (Fig. 100.)

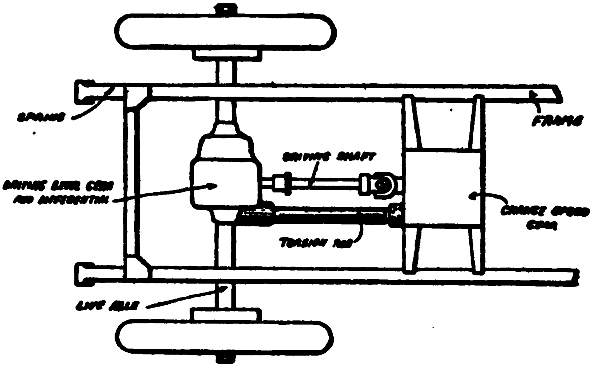


FIG. 100.—TORSION ROD.

In Figure 101 is shown a car with **double-chain drive,** in which the bevel gears that change the direction in which the power is applied are contained within the **gear case** that incloses the change-speed mechanism. As will be seen from Figure 91, the bevel gears connect the square shaft with the **jack shaft,** which is a shaft passing across the

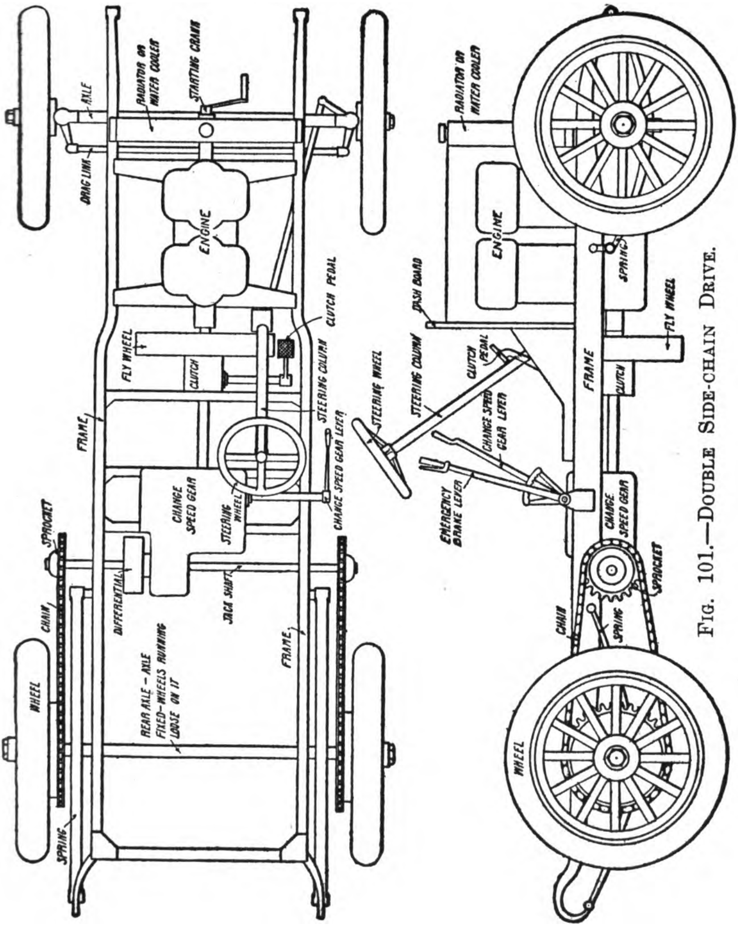


FIG. 101.—DOUBLE SIDE-CHAIN DRIVE.

car, and bearing on its ends the sprockets by which the wheels are driven. This type of drive requires the use of a **dead axle,** which is stationary with the wheels running loose on its ends, like the axle and wheels of a coach. An axle of this type may have great strength with light weight, and is usually a manganese-bronze or steel forging. The sprockets on the rear wheels are bolted to the spokes, and should be, of course, exactly in line with the sprockets on the jack shaft in order that the chains may run true.

DIFFERENTIAL

When a car takes a corner, the outside wheels make a larger curve than the inside, and cover a longer distance. As the front wheels are loose on the axle, they accommodate themselves to this; but as both rear wheels are driven by the engine, it is necessary to apply a device that will permit them to rotate at different speeds without interfering with their driving the car. This is

accomplished by means of a **compensating and differential gear.**

To understand the necessity for a differential, stand behind a wagon, with one hand on each tire; push, and if the vehicle is steered straight ahead, the hands will move ahead equally; but if the vehicle turns, the hand on the outside wheel will move ahead faster than the other. Now take a stick, and run it through the rear wheels so that it bears against the spokes; press it forward from its center, and if the vehicle moves straight ahead, the stick will go forward equally; but if the vehicle turns, the outside end of the stick will go ahead faster and farther than the other, although the pressure is being applied to its center.

In applying a simple form of differential the axle is divided into two parts, to the inner ends of which are fitted bevel gears, these being held at a fixed distance apart by the construction of the housing (Fig. 102). Between the bevel gears and in mesh with

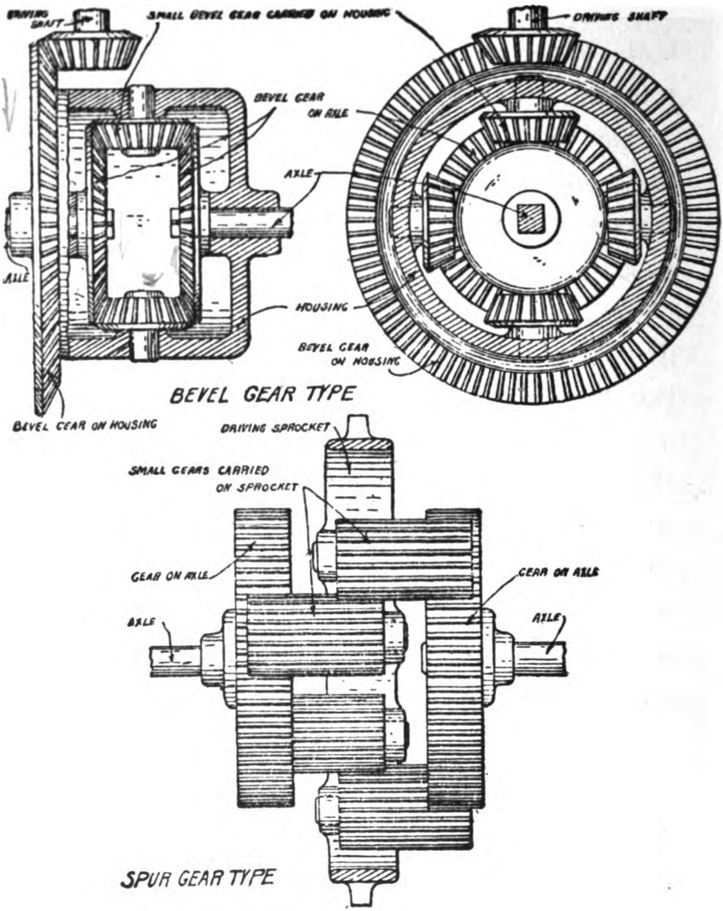


FIG. 102.—DIFFERENTIALS.

both of them are small bevel gears, or **pinions**, which may revolve on short studs carried on a ring so that they are a fixed distance apart. When the ring is revolved it carries with it the studs and pinions. The ring forms a housing that incloses the differential, and is driven by the single chain or driving shaft. To understand the action of the differential, imagine the rear wheels of a car to be jacked up clear of the ground so that they are free to revolve, and the housing to be revolved by hand. As it turns, the driving wheels will turn also, for the resistance to each is the same, and the pinions, being in mesh with both bevel gears, cannot revolve on their studs. If one of the wheels is now held stationary and the housing revolved, the bevel pinions will revolve on their studs, and roll around on the stationary gear; this will drive the gear of the free wheel at twice the speed of the housing. The revolving of the housing in the first instance caused the wheels to turn equally at the speed of

the ring, and in the second permitted one to remain stationary while the other turned at twice the speed of the housing, the speed of the latter being unchanged. The first is the effect when the car moves straight ahead, and the second the result if the car could make so short a turn that it would pivot on one wheel.

With the wheels jacked up, hold one hand lightly against one of the wheels, so that, while it may turn, there is more resistance to it than to the other. If the housing is now revolved, the bevel pinions will revolve on their studs, and roll slowly around the gear of the wheel that presents the resistance, the free wheel being revolved at a higher speed than the housing. This is the condition when the car takes a corner, for there is then more resistance to the inside than to the outside wheel, and it slows down; this will start the pinions revolving on their studs, and they will drive the outside wheel correspondingly faster.

With the housing revolving at a fixed speed, the outside wheel will revolve as much faster as the inner wheel is revolving slower; for an illustration, if the housing makes fifty revolutions a minute, and the inner wheel is slowed to forty, the outer will be driven at sixty revolutions.

If one wheel of a jacked-up car is revolved by hand, the other wheel will revolve in the opposite direction. This is caused by the housing remaining stationary and the pinions being revolved on their studs by the turning of the wheel, the movement being transmitted to the free bevel gear and wheel in the reverse direction.

The bevel gear differential described was the early type, but a more recent design employs spur gears. The axle ends carry spur instead of bevel gears, these being in mesh with other spur gears that are long, but of small diameter. These small gears are in pairs, as shown in Figure 102, being in mesh with each other at their inner ends, and each

member of a pair meshing with one of the axle gears. The small gears revolve on studs supported by the housing that is revolved by the drive, the studs in this case being parallel with the axle instead of at right angles to it, as are the studs in the bevel-gear type.

If the small gears meshed only with the axle gears, and not with each other, revolving the housing would cause them to roll around the axle gears, all rotating on their studs in the same direction, and the axle gears remaining stationary. Being in mesh with each other, they cannot revolve in the same direction, for when two gears are in mesh they must revolve in opposite directions. Thus the small gears cannot roll around on the axle gears when the housing is revolved, and if there is equal resistance to the turning of the wheels, the small gears will not revolve on their studs, but will carry the axle gears with them.

If the car is turning a corner, the greater resistance to the inner wheel will cause the

small gears to revolve on their studs, rolling around the resisting gear and driving the other correspondingly faster.

On cars with double-chain drive, the differential is fitted to the jack shaft, and of course receives the drive from the change-speed mechanism through its housing.

Both the driving-shaft and double-chain drive have points of advantage and of weakness, and each type has its advocates. For the double chain, great strength can be claimed with light weight, as the axle is in one piece, and perfectly adapted to support the car. Against it is the difficulty of keeping the chains properly lubricated, and their consequent wear and stretching. The driving-shaft type has the advantage of the perfect lubrication of the parts, for all may be inclosed and running in oil or grease; the rear axle must be divided, however, which requires it to be heavily braced in order that the weight imposed on it may not bend or

spring it out of line. Where a bent dead axle can be straightened by a blacksmith, a similar condition in a live axle requires the services of an expert mechanic; on the other hand, bevel gears make less noise than chains.

DRIVING-GEAR RATIOS

Even when on the direct drive, the crank shaft makes more revolutions than the rear wheels, in order that the momentum of the moving parts of the engine may be sufficient to keep the car in motion. On shaft-driven cars, the bevel on the driving shaft has fewer teeth than that on the axle, so that it revolves more than once to one revolution of the axle. On chain-driven cars, the driving sprockets are smaller than those driven. This **driving-gear ratio**, as it is called, varies from one and a half to three and a half, or, in other words, the wheels revolve once while the driving shaft or sprocket makes from one

and a half to three and a half revolutions. Other conditions remaining equal, a higher driving gear gives the car lower speed, but greater ability in hill-climbing and the traversing of heavy roads.

CHAPTER XV

RUNNING GEAR

THE steering of a motor car, or the change in the direction of its movement, is effected by changing the position of its steering wheels, usually those in front, in relation to the rear wheels. In a horse-drawn vehicle, the axles are parallel when it is moving straight, as are also the planes of its front and rear wheels. To turn the vehicle to one side or the other the front axle is swung so that it is out of parallel with the rear axles, the vehicle turning to the side on which the axles would meet if they were extended. This construction requires the wheels to run loose on the axle, and the axle to be permitted to swing on the pivot by which it is attached to the body of the vehicle.

Such a construction would be imprac-

ticable for an automobile, because the weight resting on the front axle would require the

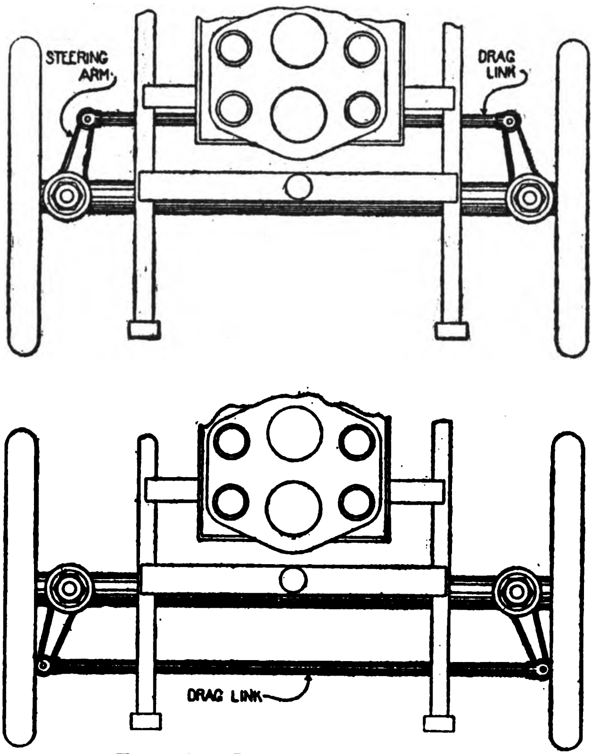


FIG. 103.—DRAG LINK POSITIONS.

pivot to be of greater strength and stiffness than could be conveniently obtained, and be-

cause of the effort that would be necessary to swing the axle in steering. The front axle of an automobile is stationary, and the steering effect is obtained by pivoting short pieces to its ends, these carrying the wheels. From these pivoted ends, called **knuckles,** extend short **steering arms,** which are connected by a **drag link,** so that moving the drag link moves the pivoted ends of the axle and the wheels to correspond (Fig. 103).

For a wheel to follow a curved path without slipping, it must be at all times tangent to the path, and will be perpendicular to a radius of the curve at that point. The front axle of a horse-drawn vehicle points toward the center of the circle on which the vehicle may be turning and forms part of the radius, the wheels, of course, being perpendicular to it (Fig. 104, C). As the main part of the front axle of an automobile is stationary, only its pivoted ends may point to the center of the circle, and this must occur in order that the wheels may be tangent to the curve

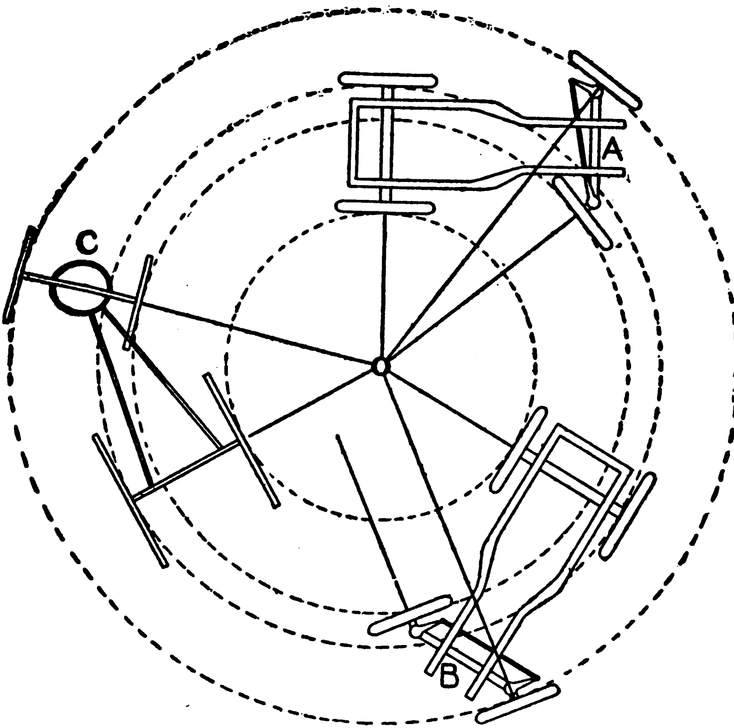


FIG. 104.—HOW VEHICLES TURN.

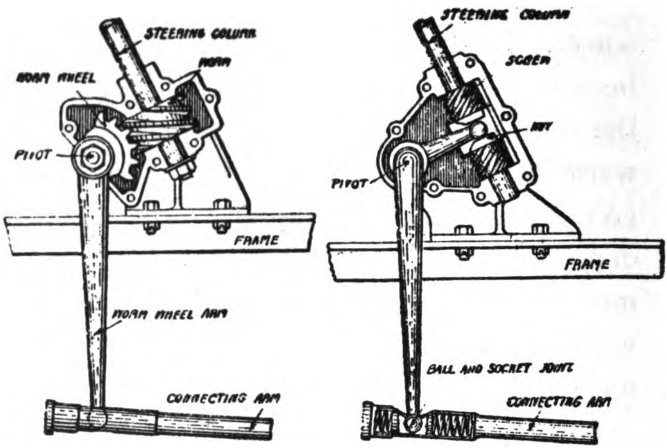
(Fig. 104, A). Both axle ends point to the center, but along different radii; if both pointed along the same radius, it would necessitate their being in line with the stationary part of the axle, which then also would be part of the radius. As the axle ends are in line with different radii of the same curve, it follows that the wheels are perpendicular to different radii, and not parallel with each other, a condition impossible in horse-drawn vehicles. The front wheels of an automobile are parallel with each other when the axle ends are in line with the stationary part, but go out of parallel as soon as they are at an angle with it, as is the case when the car takes a curve.

If the steering arms project from the knuckles at right angles to the axle ends on which the wheels revolve, moving the drag link would move each knuckle through an equal angle, and the wheels would be parallel at all times (Fig. 104, B). This is prevented by so constructing the knuckles that

the steering arms incline toward each other, with the result that, when the drag link is moved, one of the wheels swings through a greater angle than the other, the difference between the angle of each steering arm and the stationary part of the axle increasing with a greater movement of the drag link.

The control of the drag link is obtained either by a **steering lever** or **wheel.** When the steering lever is moved by the driver, the drag link is moved to correspond by a connecting rod, and this type is usual in small cars. It is impracticable for heavy cars because it is **reversible**; that is, the moving of the steering wheels moves the lever, and a firm grasp is required to prevent the shock of striking a stone or rut from tearing the lever from the hand and changing the course of the car. The **irreversible** type is used for all but the lightest cars, and while it permits the driver to change the direction of the front wheels it prevents any movement from being transmitted from the wheels to the

steering wheel or lever. The **screw-and-nut type** of irreversible steering mechanism (Fig. 105, B) consists of a heavy screw at-



A B

FIG. 105.—STEERING MECHANISMS. A, worm and worm-wheel steering gear; B, nut and screw steering gear.

tached to the lower end of the shaft that revolves when the driver turns the steering wheel. The screw passes through a nut that is held in guides so that it cannot revolve, and is therefore moved up or down when the screw is turned by the steering wheel. From the nut extends an arm that is connected to

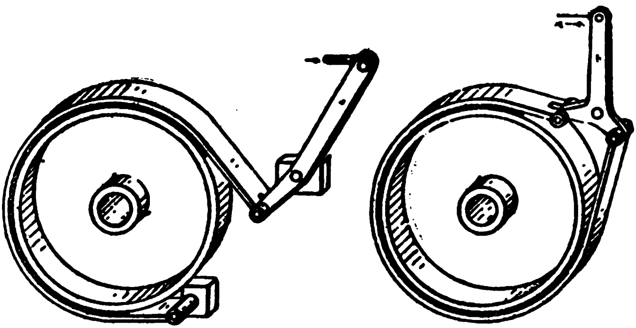
the drag link, so that its movement is transmitted to the wheels. The turning of the steering wheel thus moves the nut and the front wheels, but a movement of the front wheels from any other cause is prevented, because no pressure on the nut can revolve the screw. Another type is the **worm-and-worm wheel**, or **worm-and-segment** (Fig. 105, (A), which, while of different construction, depends on the same principle that the movement of the worm or screw can move a worm wheel or nut in mesh with it, but the movement cannot be reversed.

The stationary part of the front axle of an automobile is usually a forging, and must be of considerable strength in order to support the weight imposed upon it by the engine. It is usually bent down in the center, in order that it may be the lowest point of the mechanism, thus to receive possible blows of stones or other high points of the road that would cause serious damage should they strike the crank case or fly wheel.

BRAKES

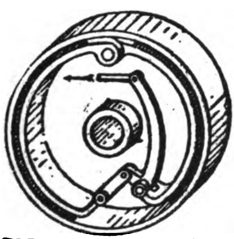
The brakes used in controlling the speed of an automobile may be as many as four in number, and there should be at least two, for on them depends the safety of the car. Brakes are of two types, **expanding** and **contracting**, and usually operate through the friction between a drum and a band that surrounds it, or blocks that press against its inner surface. The **band** or **contracting** brake may be either **single-** or **double-acting**, the latter being by far the better. In a single-acting band brake (Fig. 106) a flexible steel band surrounds the drum, one end being made fast to the frame of the car or some other stationary part, and pressure applied by drawing the free end. The friction caused by the binding of the leather or fiber lining of the band on the drum restrains the movement if the drum is revolving in the opposite direction to the pull, but there is little effect if the revolution is in the same

direction as the pull. In the double-acting type, both ends of the band are pulled, and the drum is prevented from revolving in



SINGLE ACTING BAND BRAKE DOUBLE ACTING BAND BRAKE

FIG. 106.—THREE VARIETIES OF BRAKES.



INTERNAL EXPANDING BRAKE

either direction. The single-acting type will be satisfactory when the car moves forward, but will not hold it from running downhill backward, while the double-acting brake holds it in either direction. The expanding brake usually consists of two bronze shoes, of such shape that they fit the

interior surface of the drum. The shoes are pivoted together at one end, and so arranged that the pull of the brake pedal or lever expands them, binding them against the drum (Fig. 106). When pressure is not being exerted, a coil spring, not shown in the diagram, holds them together and out of contact with the drum.

Brake drums are usually attached to the spokes of the rear wheels, and one drum often serves for both an expanding and a contracting brake. Brake drums are also applied to the jack shaft, or to an extension of the countershaft of the change-speed mechanism. It is usual to have one set of brakes controlled by a foot pedal, and another, called the **emergency brake**, by a lever at the side of the car. The foot brake, or **running brake**, is sometimes connected to the clutch, so that applying it throws out the clutch. The emergency brake is also connected in the same manner in some makes of automobiles, but this is not recommended,

for if it is necessary to stop the car when going uphill, the brakes must be released before the clutch can be thrown in, and the possibility of the car starting downhill backward before power can be applied, the chance of stalling the engine through this, and the danger of the combination to any but an experienced driver, make it advisable to have the emergency brake separate from any connection with the clutch.

Band brakes are usually lined with leather, to increase the friction between the band and the drum, and this often gives rise to troubles in the burning of the leather when the brake is applied for a considerable period, as in the descent of a long hill. The emergency brake has advantages in that it operates through the friction of metal against metal, but excessive heat from continued application may be enough to melt the metal and fuse together the shoe and drum. For long descents, it is well to use the motor as a brake, for it is logical to consider that

the means of propulsion may also be the means of retarding, as the wind that urges a sailboat forward may also bring it to a stop. It is obviously impossible to reverse the motor or gears, but by switching off the ignition circuit and throttling down, the forward movement of the car is caused to operate the motor, and the work necessary in driving the motor as an air compressor is sufficient to check the speed. The effect is so great that if the low-speed gears are engaged, the car will be brought to a stop even on a steep hill. Another advantage of this course is that it gives the motor an opportunity to cool, which is often necessary after a long ascent.

In case of the failure of the brakes to operate, which may result from poor adjustment or worn bands and shoes, the speed may be checked by throwing out the clutch, switching off the ignition, engaging the intermediate speed gears, and letting in the clutch very slowly. Great care must be taken that

the clutch is not permitted to bind suddenly, for that would probably result in the stripping of the gears. If the low-speed gears are engaged, the checking would be so sudden, no matter how slowly the clutch might be engaged, that the shock would probably throw the passengers from their seats.

The failure of the brakes when descending a hill produces a condition that requires skill and coolness, and danger can only be averted by a steady hand and a clear head.

Brakes applied to the rear wheels must have an equal grip on each, for if one binds more tightly than the other, the car will have a tendency to skid, or slide sideways. In the best cars this is taken care of by an **equalizer**, in which the pull of the lever or pedal is not applied directly to the brakes, but to the center of a bar, each end of which is connected to one of the bands or shoes. The lever action of this bar distributes the pull equally between the two brakes, and un-

less there is a great difference in the grip on the two drums, as might be the case if one were oily and the other dry, the effect will be the same on both sides.

TIRES

For low speeds, solid tires give good results in traction and the absorption of jolts from small obstacles, but for anything above six or eight miles an hour, pneumatic tires are a necessity in preventing the rapid shaking to pieces of the mechanism. A hard tire touches the ground at but one point, and its grip on the road will be much less than that of a pneumatic tire which, being slightly flattened by the weight it bears, presents an oval or elliptical surface to the road. While a pebble will force a solid tire to roll over it, it will sink into a pneumatic tire, and the jolt that it might cause will be entirely absorbed. Pneumatic tires are formed of alternate layers of heavy canvaslike fabric and soft rubber, and the processes through

which they are put in manufacture are supposed to effect their perfect combination; but as it is not the nature of rubber to be absorbed by the fabric, the layers are only bound together by its tenacity. The bending of the sides of the tire under the weight of the car tends to separate these layers, and water or dirt entering between them through cuts quickly brings ruin; it is obvious that the less the sides bend, the smaller will be the opportunity for the layers to work apart. A pneumatic tire should always be pumped as hard as possible, so that it stands up practically round under a loaded car. While the car will ride a little harder under these conditions than when the tires are soft, there will be greater resistance to punctures, and the life of the tires will be increased. The normal wear to a tire should give it a smooth surface, but if it is noticed that the tread is rough and uneven, it may be taken for granted that the wheels do not run true. Rear wheels will be thrown out of true by the

springing or bending of the axle, and front wheels also from this cause, but more probably from faulty adjustment of the steering mechanism or the bending of the drag link or steering arms.

The grip of the tire on the road is much affected by the nature of the surface, the traction on dry macadam being much greater than on wet asphalt. When the pull of the engine on the wheel exceeds the grip of the tire on the road, there will be a slip, and the wheel will revolve without moving the car. This will wear the tread of the tire far more rapidly than will ordinary running. The better the traction of the tires on the road surface, the less will be the tendency of the car to skid or slide sideways, and less power will be lost through the slipping of the wheels. To reduce the chance of slipping, because of wet asphalt or muddy roads, various devices are in use, all of which encircle the tread of the tire, and present a rough surface. The form in most general

use consists of chains that fit across the tread, these being detachable and used only in case of necessity. While it is often done, it is nevertheless bad practice to apply chains or other anti-skid devices to only one of the rear wheels instead of to both, for it increases the diameter of the wheel and makes a difference in the resistance against the wheel, causing the differential to operate at all times. The differential is not constructed to operate steadily, and will wear rapidly if forced to do so.

SPRINGS

In addition to tires, an automobile is fitted with springs, which are necessary to absorb the shocks and jolts that are too great to be taken up by the tires. These are usually **full** or **half elliptic** (Fig. 107), and made of flat plates, or **leaves**, of different lengths, the small being placed on the large, and all bound together at the center. The combined action of the springs and tires permits the

frame and body of the car to move in a nearly straight line, while the wheels and axles follow the inequalities of the road. When springs break, as is frequently the case, it is from the rebound of the body that

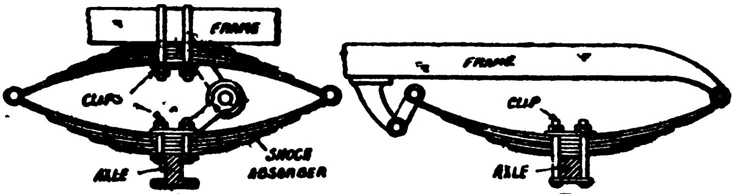


FIG. 107.—A, FULL ELLIPTIC SPRING; B, HALF ELLIPTIC SPRING.

results when the wheels drop into a deep hole, the upward movement separating the leaves, and the entire strain coming on the long leaves alone. To prevent this, **shock absorbers** are recommended, which permit the springs to have a certain amount of action, but check them if they tend to expand or compress to too great an extent. They act either by the friction between metal plates and washers, or by air or oil in a cylinder that permits a piston to move freely to a

certain degree, but presents resistance to a greater motion. Shock absorbers are placed between the axles and frame, and there should be four, two to each axle.

DISTANCE RODS

As the springs are placed between the axles and body and are flexible, it is necessary to provide some method of preventing an obstruction in the road from twisting the axle, as might result if one wheel struck heavy sand or a stone while its mate was on good surface. A twist of this sort would throw the axle out of line with the drive and bind the chain or driving shaft.

To prevent this, **radius** or **distance rods** are attached to the axle, one on each side, extending to a point well forward on the frame (Fig. 108). These rods are pivoted to the frame, and have a loose joint on the axle, so that the latter is free to move up and down, but prevented from moving forward or back. Distance rods are adjustable, and on chain-

driven cars serve to adjust the chains, which are tightened by lengthening the rods and slackened by shortening them.

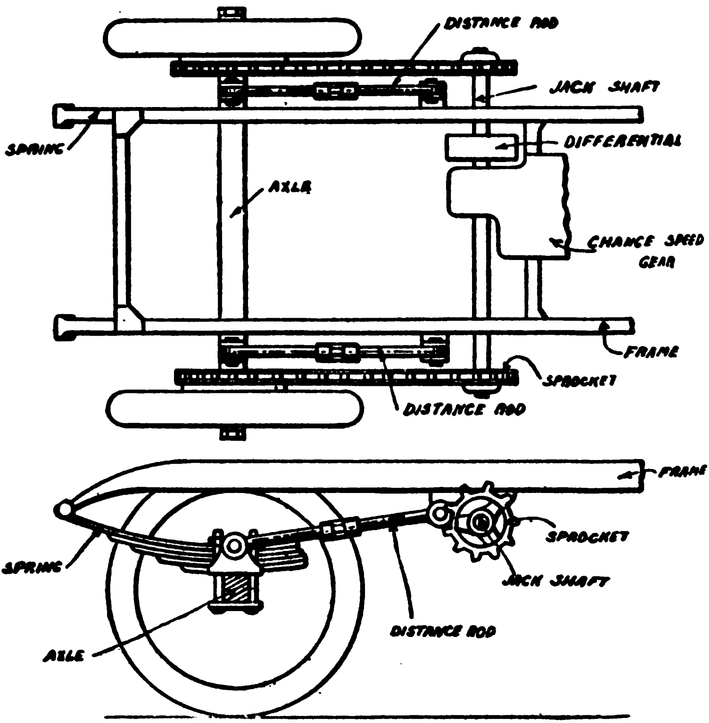


FIG. 108.—DISTANCE OR RADIUS RODS.

CHAPTER XVI

MAINTENANCE AND CONSTRUCTION

IN order that an automobile may be maintained at its highest efficiency, a constant watch must be kept over all of its parts, and repairs and replacements made as soon as the necessity is apparent. A worn bearing or loose part may continue to operate, but the wear will be far greater than would occur under normal conditions, and may result in serious breakage. A system of inspection to be gone through every time that the car is used will keep the driver informed as to its condition, and it is best to form the habit of doing this at the end of a run rather than before, for then the necessity for making readjustments or repairs will be fresh on the mind.

INSPECTION

The condition of the ignition circuit and of the compression will be shown in revolving the crank shaft twice, and the action of the carburetor may be ascertained at the same time. Pushing the car across the floor will show the presence of tight brakes or wheel bearings, and the tires may then be examined for cuts. Beginning at the front of the car, every bearing not fed by the lubricator should be oiled, and all grease cups given a slight turn, those that are empty or nearly so being filled. While this is being done, a watch may be kept for nuts and bolts that may have been loosened by the vibrations.

WASHING

The car should be washed with clear, cold water only, and mud floated off; to remove mud by rubbing or any other method than sluicing it away by the action of a gentle stream of water will scratch the varnish and

ruin the appearance of the car. When clean, the varnished parts may be dried with chamois or wash leather, and the finish retained by a light coating of a good furniture polish, which is to be immediately dried by rubbing.

The tires may be cleaned by sponging, but water should not be allowed to settle in the bead. On cars having the gravity system of gasoline feed, the water should not be permitted to splash on the tank, for it will enter through the vent. Water should also be kept from the upholstery, for if it enters the folds and buttonholes it will cause rotting.

THE TIRES

Light and heat are the worst enemies of rubber; spare tires should be kept in a cool, dark place, and protected from dust and moisture. French chalk, or some similar preparation, should be well dusted over the shoes and tubes, and if the tubes are folded, they should occasionally be opened and re-

folded in fresh places, to prevent the formation of creases. The spare tire that is carried on the car should be kept in a casing, and because a dark surface will absorb more heat than a light, the casing should be tan, gray, or white rather than black. The casing should be as proof as possible against moisture, but for safety should occasionally be removed and aired. The position of the shoe in the holders should be changed every little while, in order that the straps may not cut into the bead.

The tires on the wheels should frequently be examined, and any cuts filled with strong cement, for otherwise water and sand will work in to form blisters and to separate the layers of fabric from the rubber. The cutting of tires can be reduced by withdrawing the clutch when crossing broken stones, the car coasting over them; driving the car over such a surface will force the tires against the sharp edges, and cutting will result more surely than when the tire rolls over them.

CARE OF THE ENGINE

The carbon deposits that will form in the combustion space will in time tend to stick the piston rings in their grooves, and this may be prevented by squirting a few drops of kerosene oil into the cylinders and cranking the engine to distribute it. This should be done at the end of a run, and the engine permitted to stand in that condition. The first explosions will vaporize the kerosene and drive it off unless too much has been used, when there will be a tendency to foul the spark plugs.

The lubricating oil should be drained out of the crank case every five hundred miles, and the case washed out with kerosene before refilling it with fresh oil. Gasoline has too great a cutting action to warrant its use for this, as it cleans down to the bare metal, while kerosene removes the dirt and grease, leaving a good surface. The case should be filled with oil to such a depth that the con-

necting rods will dip into it from a half inch to an inch.

The same should be done with the change-speed gear case every thousand to fifteen hundred miles, for the particles of metal that will be ground from the gears will injure the teeth and bearings. In refilling, the smallest gear should project about an inch into the oil. If the differential is packed in grease, it will run for an entire season with one filling, but if it runs in oil it should be cleaned and washed two or three times a year. The bevel gear case of a shaft-driven car should receive the same attention.

CARE OF CHAINS

Properly lubricated chains should run for at least a thousand miles without attention. Because of their exposed position they should be protected against undue wear, and this is best attained by soaking them, when thoroughly cleaned, in melted tallow, working each joint in order that the liquid may

penetrate. The chain should be hung up to cool and dry, the surplus tallow being wiped off. The hardened tallow in the joints will prevent grit from working in, and is a lubricant as well. To clean a chain, soak it in kerosene, working each joint to remove the grit. The stretching of the chain may be taken up by lengthening the radius rods, but when the stretching reaches a point that permits it, the chain should be shortened by the removal of a link, and the rods readjusted. If a complete chain is not carried as a spare part, the kit should always include a few extra links for emergency repairs. These are not difficult to apply, being secured in position by nuts instead of by burring over the ends of the rivets.

VALVE GRINDING

To grind a pitted or worn mechanically operated valve, the pressure should be released by compressing the spring and removing the key or other device by which it

is held in place. On removing the plug over the valve pocket, the upper surface of the valve disk will be exposed, and it will be found to be provided with a slot. While many grinding pastes may be purchased, good results will be obtained by mixing machine oil with flour of emery until it is thick. Plugging the opening from the valve pocket to the combustion space with cotton waste to prevent the paste from entering the cylinder, spread it on the valve disk and seat, and rotate the disk on its seat with a screwdriver, preferably by means of a bit brace. Every little while the disk should be lifted and replaced on the seat in a new position, in order to distribute the wear evenly, and the grinding continued until a smooth surface shows all around both disk and seat. It is not necessary to smooth the entire surface of the disk and seat, for the pressure will be retained by a narrower surface.

An automatic valve may be removed from the cylinder by unscrewing or unbolting its

cage, and after releasing the spring the cage may be held in a vise while the grinding is performed.

After grinding, all traces of the paste should be removed by washing with gasoline, for any particles that remain will cause rapid wear. When replacing the spring, that of the mechanically operated valve will be found difficult to compress to the point at which the key or washer may be slipped into position, and to simplify this many engines are built with a knob or boss on the cylinder to serve as a fulcrum by which a forked lever may be used. If this is not the case, the spring may be sufficiently compressed in a vise, and bound endwise with wire to retain it, the wire being cut when the spring and key are in position.

CARE OF STEERING MECHANISM

A failure of the steering mechanism will cause a wreck more surely and quickly than the break-down of any other part of the car,

and the best protection is absolute knowledge that it is in perfect condition. All joints should be kept well lubricated, and protected from dust; the leather protectors that are furnished do not accomplish this any too well, but they are much better than nothing, and if the joints are packed with grease before applying them, the results will be good. While guarding against stiffness, there should be very little play or lost motion in the mechanism, and the parts should be frequently examined for bent rods and loose joints. A bend in the drag link or steering knuckles will throw the front wheels out of true, in which case the tires will be badly worn. When going straight ahead, the wheels should be parallel; if this is the case, the angles of the steering arms will give the proper track when making a turn.

CARE OF SPRINGS

The springs of an automobile are in constant motion, and should be as carefully

lubricated as the other parts of a car. The spring hangers by which the two halves of a full elliptic spring are joined, or by which a half elliptic spring is attached to the frame, are often provided with grease cups, but in the absence of these the parts should be frequently oiled. Once a season fresh lubricant should be applied to them. The leaves of a spring may usually be separated enough for this by jacking up the body, applying the jack to the frame; the springs will thus be relieved of the weight, and the leaves will separate sufficiently to permit heavy grease or graphite to be introduced between them by means of a table knife. If the springs are too heavy to permit this, they must be taken apart, which may be done by removing them from the car and releasing the clips by which they are held together. In reassembling a spring, it may be clamped in a vise, when the clip may easily be secured.

ADJUSTING VIBRATORS

In adjusting the vibrators, the best guide is the running of the engine. The musical tone that they make is misleading, for a difference in the steel of which the blades are made, or in the quality of the core, will produce a difference in the tone, and because two vibrators sound alike is not proof that they are producing equal secondary sparks. With a one-cylinder engine, the adjusting screw may be turned until the engine is running at its best, while at the same time there is the smallest spark between the vibrator contacts. The adjustment of the vibrators of a multicylinder engine is proceeded with along similar lines, all of the blades but one being held down, while the free blade is adjusted until the best results are obtained in the operation of the cylinder to which it corresponds, and the smallness of the spark between the vibrator contacts. When one is correct, it is held down and another released,

this process being continued until all are adjusted.

ADJUSTING THE CARBURETOR

When adjusting a carburetor, it must be remembered that the proportion of liquid gasoline to air in a correct mixture is very small; because this is not well understood, a rich mixture is present far more commonly than a poor one. To begin at the beginning, close both the gasoline and auxiliary air inlets, and, opening the gasoline adjustment a very little at a time, crank the engine until combustion is secured, the spark being retarded and the throttle nearly closed. When the engine runs, open the relief cocks and note the color of the flame that shoots out. A poor mixture will produce a yellow flame, and a rich mixture a red and smoky flame, with black smoke at the exhaust and a smell of gasoline. The flame of a correct mixture is blue and hardly visible. On securing a correct mixture at

low speed, advance the spark and open the throttle to speed up the engine, and the mixture will at once become too rich. Adjusting the auxiliary air inlet by weakening the tension of its spring will bring the mixture to approximately correct proportions. A more careful adjustment under road conditions can be obtained by adjusting the air inlet while the car is being operated, for the position of the carburetor is usually such that this may be done while standing or kneeling on the running board.

Faulty adjustment of the carburetor is often suspected when the real source is in the throttle or governor connections. The bending of a rod connecting the throttle with either the foot, hand, or governor control, or the wear of the joints, will throw the carburetor out, and the possible failure of these parts must be borne in mind accordingly.

SETTING THE VALVES

In setting or timing the valves of a gasoline engine, the point to be considered is the closing of the exhaust valve, for upon this good results depend. If this valve is held open too long, the burned bases driven out will be drawn back into the cylinder, and if it closes too soon the greatest possible quantity of burned gases will not have been expelled. The many experiments carried on by the manufacturers, and the attention that they must pay to this point, result in the delivery of cars with valves correctly timed, and usually with marks made on the two-to-one gears to guide in resetting them. In the absence of these guides, the setting of valves need not be difficult, although experimenting is required to secure the best results. The first step is to locate the position of the piston in the cylinder. There is always an opening in the cylinder head—a relief cock, the spark-plug opening, or other—and a stiff

wire may be dropped through it, with its lower end resting on the piston and its upper end projecting. As the piston is moved by cranking the engine, the wire will move with it, and is to be marked with a file at its highest and lowest positions. While no fixed rule can be laid down, it may be said that in general the exhaust valve should close when the piston has made from $\frac{1}{64}$ to $\frac{1}{32}$ inch of its outward stroke. The two-to-one gears having been unmeshed, the cam shaft may be revolved in its bearings by hand; cranking slowly, move the piston down from its highest point to that at which the exhaust should close, and hold it there. Revolve the cam shaft until the nose of the cam is passing from under the roller of the valve-lifter rod, and the valve just closed. This point may be accurately ascertained by placing a strip of thin paper between the valve-lifter rod and valve stem; when the cam is acting on the valve-lifter rod, the paper will be pinched, but the seating of the valve will release it.

When the paper can be pulled out, mesh the two-to-one gears, and the relations thus established between the crank and the cam shafts will be maintained. Cranking the engine a few times, using the strip of paper, will verify results, and the engine may then be started and the effect noted. If the running is not satisfactory, unmesh the gears, and mesh them with a difference of one tooth, first one way and then the other, noting results, and retaining the most satisfactory position.

Cams are often cut in one piece with the cam shaft, and the gear keyed on the end; there is therefore no chance to make a finer adjustment than what is permitted by shifting the gears one tooth at a time. On multicylinder engines, one cam shaft operates all of the exhaust valves, and the setting of one valve sets all.

When inlet valves are of the mechanically operated type, but controlled by a separate cam shaft, this must be set in a similar man-

ner. The nose of the cam should just be coming into contact with the push rod roller at the instant when the exhaust valve is completely closed. This should occur as the piston begins to move outward on the inlet stroke, the exact position being determined by experiment.

When the cams are so badly worn that if they are set to open correctly they close too soon, the best remedy is a set of new cams; for while the brazing of a strip of brass to the sides of the cams can be resorted to, the result is only temporary at best, and not as accurate as that secured by the use of new cams.

While the tension of the spring of an automatic valve is sometimes controlled by a nut, its adjustment usually depends on the stretching of the spring to strengthen it, or the cutting off of part of a turn to weaken it. The tension should be adjusted, one cylinder at a time, until the best results from each are secured.

LINING UP THE WHEELS

When the car is moving forward on a straight line the wheels should be parallel in so far as their forward direction is concerned. In a far greater number of cases than is realized that is not the condition, with the result that the wheels will be making an angle with the line in which the car is moving. In consequence, the tires will be subjected to a dragging action in addition to their rolling movement, which will wear the outer casings far more rapidly than is justified by the distance traveled.

The casings of the rear wheels are usually slightly rough, due to the slight but frequent slipping caused by the quick application of power or of the brakes, and also due to some extent to the action of the springs. The front wheels, on the contrary, should have a rolling motion, and the surfaces of the casings should always be smooth. If they are rough it indicates that the wheels are out of true.

If the car is to be kept in thoroughly good condition, the lining up of the wheels should be checked at monthly intervals. The apparatus required is simple, consisting of two stout sticks seven feet long and two pieces of cord longer than the car.

Each stick is to have two notches cut in it near its ends, the distance between the notches being a few inches greater than the length of the rear axle. The distances between the notches on the two sticks should be identical. The two pieces of cord are then to be tied to the sticks at the notches. Two chairs should now be placed, one in front of the car and one behind it, with their backs toward the car, and the sticks laid on the seats of the chairs with the cords drawn taut. The two strings will then be parallel at approximately the height of the axles. By moving the chairs slightly the strings may be brought parallel to the frame of the car, and when once in position should not be moved.

Measurements should then be made from the string to the felloe of one of the rear wheels, and if the position of the wheel is true, the distance from the string to the part of the felloe in front of the hub should be equal to the distance from the string to the part of the felloe behind the hub. A similar measurement should then be made to the other rear wheel to ascertain its position. If the axle housing is rigid, the relation of each wheel to its string will be identical, for an axle housing in good condition will hold the wheels parallel.

If through the sagging of a spring, the slipping of a spring clip, or through a misadjustment, the rear axle is out of true, this fact will be indicated by measurements that will show the rear wheels to be out of parallel with the strings. The defect should be corrected.

With the rear wheels running true, the steering gear should be worked to bring one front wheel parallel to its string, the meas-

urement being made to the felloe at points in front of and behind the axle. With the wheel in that position the position of the remaining front wheel should be measured, and if it is not parallel to its string, as is frequently the case, the reason for this should be determined. It may be due to the bending of the drag link or of the front axle, or one of the steering knuckles may be bent. The drag link is usually provided with an adjustment, and by screwing or unscrewing it the wheels may be made parallel.

The operation of checking up the lining of the wheels requires only a few minutes' time, and the saving in the wear of tires makes it well worth while to perform the operation frequently.

CHAPTER XVII

CAUSES OF TROUBLE

PRACTICE and experience are the best instructors in keeping the car running, and the operator quickly acquires the ability to recognize the source of trouble from the action of the engine in failing to deliver power, or from the manner in which it stops. Each part of the mechanism may be counted on to give trouble, and the possibilities are numerous, but in general it may be said that an interference with the proper operation of the engine may be laid to the failure of the ignition system or gasoline supply, a defect of the combustion space in not retaining the pressure, or the overheating of the engine.

PRESSURE GASOLINE FEED

In order to retain the necessary pressure, the tank and its connections should be tight.

The cap of the tank should be provided with a proper gasket, and should be kept screwed up tight. If there is a leak in one of the joints of the pressure pipe or the gasoline pipe, it should be unscrewed to ascertain if the parts are in good condition. In reassembling the parts, the threads should be coated with shellac to prevent them from unscrewing.

GRAVITY GASOLINE FEED

The cap of the tank will have a small hole drilled through it to permit the entrance of air to the tank to occupy the space left by the flow of gasoline to the carburetor. If this hole is clogged, the entrance of air will be prevented and the tank will become **air-bound.**

A condition of this sort is deceptive, for it gives the same indication as an empty gasoline tank. When the tank cap is unscrewed air is admitted, and the engine will run until the tank again becomes air-bound.

The remedy is to clean out the dirt or to provide a small hole for the entrance of air if one is not provided.

The gasoline line should invariably be fitted with a strainer which will remove particles of dirt and will separate the water. The drain cock of the strainer should be opened for a few minutes every three or four days to let out the impurities.

CARBURETOR

The principal trouble given by a carburetor will be due to dirt, which will lodge in the float valve and cause flooding, or will clog the spray nozzle.

It occasionally happens that a metal float becomes leaky or a cork float becomes soggy with gasoline; in either case the float by becoming too heavy will cause flooding. A leaky metal float should be held under hot water to vaporize the gasoline; the leak, which will be shown by the escaping gas bubbles, should be marked, and when the

float is empty should be closed by a tiny drop of solder.

A soggy cork float should be dried out in an oven and then coated with shellac.

An instruction book covering the type of carburetor used should be secured from the manufacturers.

MAGNETO

The most usual trouble with a magneto is due to dirt, which will interfere with the circuit breaker. The platinum points should be kept clean and free from oil in order to operate properly. The lever should also be free on its pivot.

An instruction book explaining the use of the magneto should be secured from the manufacturers, and it will be found to contain full directions for the care of the instrument, as well as directions for the location of trouble.

DRY CELLS

Dry cells should be kept in a tight box and protected from dirt and dampness. If their pasteboard jackets become wet they will form conductors between adjoining cells and cause a waste of current. Oily, dirty or loose terminals may prevent the current from passing to the circuit.

A dry cell will give its most intense current when it is new, and will waste away with age even if it is not being used; when buying cells, fresh ones should always be insisted upon. When a dry cell has been in use for some time it becomes exhausted; it will give a current when the switch is first thrown on, but will quickly fail. An exhausted cell is useless and should be replaced. When a dry cell is chilled it will not give as intense a current as when it is warm. If the cells do not give sufficient current to operate the motor it should be noted, first, that there are enough cells connected

in series to give the required voltage; second, that the connections between the cells are properly made; and, third, that the terminals are clean and tight.

STORAGE CELLS

A storage cell should be kept thoroughly charged, even though it may not be in use. A good voltmeter should be provided, and when the voltage of the battery drops to 1.8 volts a cell or less, the battery should be recharged without loss of time.

VIBRATOR COIL

A vibrator coil will give trouble through the platinum points of the vibrator being dirty or worn, or the vibrator blade being out of adjustment or loose.

The blade should be adjusted to make the engine operate properly with as little sparking as possible at the vibrator platinum points. If the sparking is intense at the

points, they should be cleaned and smoothed with a very fine flat file. If the sparking continues in spite of changes in adjustment, and the engine cannot be made to run properly, it indicates an internal defect that will require the coil to be returned to the manufacturer.

SPARK PLUGS

A spark plug will give trouble through the insulation becoming fouled with carbon deposit. The plug may be cleaned by the use of gasoline and a stiff brush. The spark plug points should form a gap of not less than $\frac{1}{50}$ and not greater than $\frac{1}{32}$ inch. The gap may be adjusted by bending the electrodes. Porcelain or mica insulation will crack or become leaky with use, and if the plug is of a type that is screwed together, the loosening of the parts will cause a leakage of compression.

If spark plug trouble develops on the road, the quick remedy is to replace the defective plug with a perfect one.

CABLES

The insulation of the cables should be sufficiently perfect to retain the ignition current. The engine should be occasionally run in the dark, which will make visible any leakage of current. All terminals should be tight.

SWITCH

A defective switch may cut out the current entirely, or may cause an intermittent interruption of the current due to the vibration of loose switch parts.

TIMER

Irregular firing will be caused if the timer is dirty or packed with grease that is too thick, or if the timer spring is weak. A loose timer connection or a timer that is loose on its shaft will also cause misfiring.

COMPRESSION

If the engine does not develop power the trouble will frequently be found to be a loss of compression in one or more cylinders, and this fault may also cause misfiring.

Compression will find an opportunity to leak through a worn valve or because of weak valve springs. Leaks may also occur through the spark plug parts being loose, or through the plug itself not being tightly screwed into the cylinder. The pet-cock may be loose, the piston rings and cylinder walls may be worn or scratched, or the piston rings may be broken.

CHAPTER XVIII

EFFECTS OF TROUBLE

THERE is a reason for every trouble that develops in the operation of the car, and as a general thing this reason may be determined by observation. The cause of improper operation cannot be determined by guessing at it; if the action of the mechanism is understood there is no difficulty in locating a fault by a study of the effects.

In locating engine trouble it should be remembered that the engine cannot help but run if it receives a proper charge of mixture and if the mixture is compressed and ignited properly; provided of course that the bearings are not too tight, the crank shaft is not broken or some other vital part is not defective.

The most usual causes of defective operation are as follows:

Engine will not start

No ignition.

No carburetion.

No compression.

Engine starts, but will not continue running

Insufficient flow of gasoline to the carburetor.

Dirt in carburetor.

Exhausted battery.

Explosions stop abruptly

Broken wire.

Loose terminal.

Explosions weaken and stop

No gasoline.

Exhausted battery.

Slipping of magneto or timer drive.

Steady miss in one cylinder

Defective spark plug.

Stuck or broken valve or valve spring.

Broken wire controlling that cylinder.

Occasional miss in one cylinder

Defective spark plug.

Stuck valve or broken valve spring.

Loose connection of wire controlling that cylinder.

Water in cylinder.

Occasional miss in all cylinders

Dirt or water in gasoline.

Loss of ignition.

Engine does not develop full power

Weak compression.

Piston or bearings too tight.

Insufficient lubrication.

Defective cooling.

Ignition out of time.

Poor mixture.

Slipping clutch.

Tight brakes or transmission bearings.

Engine overheats

Too much running on low gear.

Spark retarded too much.

Insufficient lubrication.

Defective cooling.

"Popping" in carburetor

Mixture too weak.

Inlet valve worn or stuck.

Knocks and pounds

Ignition too early.

Loose bearings.

Loose cylinder.

Loose fly wheel.

Engine base loose on frame.

Hissing

Compression leaks.

Leaky inlet or exhaust pipe.

Engine kicks back on starting

Ignition too early.

Engine will not stop

Heavy carbon deposit in cylinder.

Spark plug electrodes so thin that they glow and ignite the charge.

Muffler explosions

The result of a missing explosion and the ignition of the fresh charge in the muffler.

Black smoke at exhaust

Mixture too rich.

White or blue smoke at exhaust

Too much oil.

LUBRICATION TABLE.

	PART.	LUBRICANT.	QUANTITY.
Require constant attention.	**Engine cylinder**	**Cylinder oil**	**6–12 drops per minute.**
	Engine bearings	**Cylinder oil**	8 drops per minute.
	Fan bearings	**Cylinder oil**	1 drop every 2 minutes.
	Magneto, plain bearing	**Cylinder oil**	Keep pockets ¾ full.
	Clutch leather	**(Vegetable), castor oil, neats-foot oil**	Wash out with kerosene once a season. If clutch slips or leather gets **hard, keep off machine oil.**
Require attention daily.	**Valve lifters**	**Cylinder oil**	**With oil-can.**
	Timer-shaft	**Cylinder oil**	**With oil-can.**
	Pump shaft drive	**Cylinder oil**	**With oil-can.**
	Magneto drive	**Cylinder oil**	**With oil-can.**
	Lubricator shaft	**Cylinder oil**	**With oil-can.**
	Clutch release	**Cylinder oil**	**With oil-can.**
	Lever bearing	**Cylinder oil**	**With oil-can.**
	Steering knuckle	**Grease**	**One turn.**
	Water pump	**Grease**	**One turn.**
	Clutch-shifting collar	**Grease**	**One turn.**
	Transmission bearings	**Grease**	**Two turns.**
	Outer bearing live rear axle	**Grease or oil**	**Two turns.**
Require attention weekly.	**Starting-crank bracket**	**Cylinder oil**	**Few drops.**
	Spring shackles	**Cylinder oil**	**Few drops.**
	Make and break tappets	**Cylinder oil**	**Few drops.**
	Pedal-shaft brackets	**Cylinder oil**	**Few drops.**
	Speed-change lever	**Cylinder oil**	**Few drops.**
	Emergency lever	**Cylinder oil**	**Few drops.**
	Brake supports	**Cylinder oil**	**Few drops.**
	Brake equalizers	**Cylinder oil**	**Few drops.**
	Control levers and joints	**Cylinder oil**	**Few drops.**
	Spring hangers	**Cylinder oil**	**Few drops.**
	Clutch; multiple disk, **steel on steel**	**Spindle oil and kerosene, or kerosene and little graphite**	
	Clutch; multiple disk, leather on steel	**No oil, little graphite**	
	Internal expanding clutch	**Thin oil**	

LUBRICATION TABLE.

	PART.	LUBRICANT.	QUANTITY.
Require attention every two weeks or every 300 miles.	Engine crank case	Cylinder oil	
	Steering gear case	Grease	3 turns or gunful.
	Transmission-case, sliding gear system	Gear case compound or heavy oils, or either, mixed with about ten per cent. of graphite	Let gears dip.
	Transmission case, individual clutch type	Light motor oil and little graphite	
	Planetary transmissions	Non-fluid oil, or oil and graphite	Fill up no higher than shaft bearing.
	Live rear axle housing	Non-fluid oil or heavy steam engine cylinder oil, grease and oil	One quart.
Require attention monthly or every 300 miles.	Magneto, ball bearing	Cylinder oil	Small amount.
	Front and rear wheel-hubs; ball or roller bearing	Grease	
	Front and rear wheel-hubs; plain bearing	Graphite and oil	
	Leather boots of steer-rod joints and steer drag-rod joints	Grease	
	Universal joints	Grease	Remove covering, inspect and repack.
	Torsion and distance rods	Oil	
	Timing gears	Non-fluid oil; graphite if exposed	
Require attention at greater periods.	Friction disk transmission	Keep oil off friction surfaces, wash off with gasoline, dress with belt dressing or French chalk	Renew friction compost every 1,000 miles.
	Chains	Chain graphite	Twice a year boil in graphite and grease after washing well in kerosene.

INDEX

P

R

S

W

(12)